Nanosurf FlexAFM

Operating Instructions

for

SPM Control Software
Version 3.1

OPERATING INSTRUCTIONS V3.1R0, BT03710-15.

Table of contents

Table of contents

PART A: INTRODUCTION TO THE INSTRUMENT

About this Manual

For your convenience, this manual has been divided into three separate parts:

PART A: INTRODUCTION TO THE INSTRUMENT will familiarize you with the Nanosurf FlexAFM system, and will explain how to set up your system and operate it on a daily basis. Among other things, it will also describes how to set up basic experiments and how to generally improve measurement quality. Part A starts with *Chapter 1: The FlexAFM* (page 15) and ends with *Chapter 6: Finishing measurements* (page 69).

PART B: SOFTWARE REFERENCE is a reference for the software that comes with the FlexAFM system. It starts with *Chapter 7: The user interface* (page 75) and ends with *Chapter 15: Quick reference* (page 265). Its content applies to Nanosurf Easyscan 2 software version 3.1, Nanosurf Translation Stage Controller software version 2.1, and Nanosurf Batch Manger software version 1.3. If you are using newer software versions, download the latest manual from the Nanosurf Support pages or refer to the "What's new in this version.pdf" file that came with the newer software. For more information on the Nanosurf Scripting Interface, refer to the online help files "Easyscan 2 Script Programmers Manual". For more information on the Nanosurf Report software, refer to the online help included with this optional software.

PART C: APPENDICES contains information that you will use less frequently, such as general maintenance and troubleshooting. It starts with *Chapter 16: Maintenance* (page 269) and ends with *Chapter 19: Technical data* (page 287).

PART A:

INTRODUCTION TO THE INSTRUMENT

CHAPTER 1:

The FlexAFM

1.1: Introduction

The Nanosurf FlexAFM system is an atomic force microscope that can measure the topography and several other properties of a sample with nanometer resolution. These measurements are performed, displayed, and evaluated using the SPM Control Software.

The FlexAFM system is a modular scanning probe system that can be upgraded to obtain more measurement capabilities. The main parts of the basic system are the FlexAFM Scan Head, the FlexAFM Sample Stage, the Easyscan 2 Controller with AFM Basic module, and the SPM Control Software.

The content of the system and the function of its major components are described in this chapter. Detailed technical specifications and system features can be found in *Chapter 19: Technical data* (page 287).

Several other Nanosurf products can be used in conjunction with the FlexAFM:

- AFM Dynamic Module: adds dynamic mode measurement capabilities for measuring delicate samples.
- AFM Mode Extension Module: adds phase contrast, force modulation and current measurement capabilities.
- FlexAFM Video Module: allows observation of the approach on the computer screen. This is useful when observation using the lenses is impractical.
- Signal Module A: allows monitoring of microscope signals and creating custom operating modes. Refer to *Section 19.4.2: Signal Module A* (page 294) for more details.
- Nanosurf FlexAFM Micrometer Translation Stage: allows locating of a position on a sample with micrometer accuracy. Should be used together with a FlexAFM Sample Stage
- Nanosurf Report: software for simple automatic evaluation and report generation of SPM measurements.
- Nanosurf Analysis: software for detailed analysis of SPM measurements.
- Scripting Interface: software for automating measurements. Refer to *Section 10.4.2: Scripting group* (page 157) and the *Programmer's Manual* for more details.
- Lithography Option: software for professional lithography applications. Refer to *Chapter 12: Lithography* (page 187) for more information.
- The Nanosurf Isostage: a highly compact active vibration isolation table.
- The Halcyonics_i4 Active Vibration Isolation Table: a large and heavy-duty active vibration isolation solution, which features load adjustment.

1.2: Components of the system

This section describes the parts that may be delivered with an FlexAFM system. The contents of delivery can vary from system to system, depending on which parts were ordered. To find out which parts are included in your system, refer to the delivery note shipped with your system. Some of the modules listed in the delivery note are built into the controller. Their presence is indicated by the status lights on the top surface of the controller when it is turned on (see *Section 1.3.2: The Easyscan 2 Controller* (page 20)).

Before unpacking the instrument, verify that the package contains the following components:

Figure 1-1: Components. The FlexAFM system

1. The Easyscan 2 Controller (optionally with built-in additional modules).
2. FlexAFM Scan Head in its wooden Scan Head Case (latter not shown).
3. Cantilever Holder; attaches to the FlexAFM scan head and allows mounting of the cantilever for measurement.
4. Cantilever Exchange Tool; stably holds the Cantilever Holder in place for a convenient cantilever exchange.
5. USB cable.
6. Mains cable.
7. Scan head cable; connects the scan head to the Easyscan 2 controller.

8. FlexAFM Sample Stage (option)
9. FlexAFM Tool set (option). The items contained in the FlexAFM Tool set are described in the next section.
10. The Easyscan 2 Installation CD (not shown): Contains software, calibration files, and PDF files of all manuals.
11. A calibration certificate for each scan head (not shown).
12. This FlexAFM Operating Instructions manual (not shown).
13. AFM Extended Sample Kit (option; not shown), which comes with a set of 10 samples and description of experiments.
14. Signal Module A connector box (option; comes with Signal Module A).
15. Two Signal Module cables (option; come with Signal Module A).
16. Scripting Interface certificate of purchase with Activation key printed on it (option; not shown; comes with Scripting Interface).
17. Lithography Option certificate of purchase with Activation key printed on it (option; not shown; comes with the Nanosurf Lithography Option).

Please keep the original packaging material (at least until the end of the warranty period), so that it may be used for transport at a later date, if necessary. For information on how to store, transport, or send in the instrument for repairs, see *Section 6.3: Storing the instrument* (page 71).

1.2.1: Contents of the Tool Set

The content of the Tool set depends on the modules and options included in your order. It may contain any of the following items:

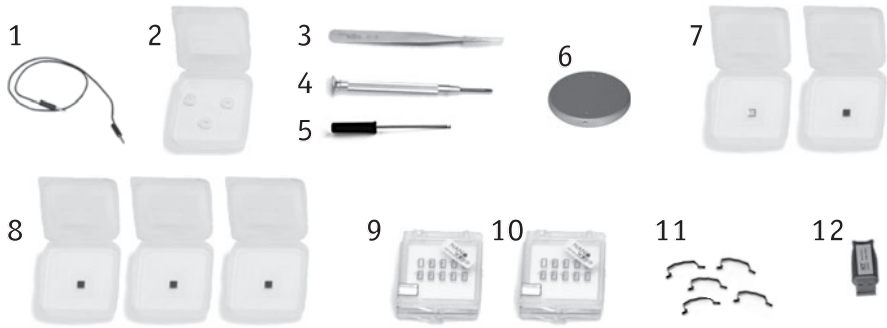


Figure 1-2: Contents of the Tool set

1. Ground cable.

2. Protection feet.
3. Cantilever tweezers: (103A CA).
4. Screwdriver, 2.3 mm.
5. Allen key with screwdriver handle, 1.5 mm (PB-212, ball point hex).
6. Sample holder (option; comes with the Flex Sample Stage).
7. Samples (option). Possible combinations are:
   a. AFM Large Scan Sample Kit (Grid: 10 µm / 100 nm, CD ROM piece).
   b. AFM High Resolution Sample Kit (Grid: 660 nm, Graphite (HOPG) sample on sample support).
   c. Two calibration samples (Calibration grid: 10 µm / 100 nm, Calibration grid: 660 nm).
8. AFM Calibration Samples Kit (option) with three calibration samples (Calibration grid: 10 µm / 100 nm, Calibration grid: 660 nm, Flatness sample).
9. Set of 10 Static mode cantilevers (option).
10. Set of 10 Dynamic mode cantilevers (option).
11. Set of 5 cantilever springs.
12. USB dongle for Nanosurf Report software (option).

1.3: Connectors, indicators and controls

Use this section to find the location of the parts of the FlexAFM that are referred to in this manual.

1.3.1: The FlexAFM scan head

The location of the scan head parts listed below is shown in *Figure 1-3: Parts of the Scan Head*.

Leveling screws
For manual fine approach of the sample (*Section 4.4.2: Manual fine approach using the leveling screws* (page 51)), and for aligning the plane of the scanner with the plane of the sample (*Section 5.2: Adjusting the measurement plane* (page 63)).

Scan Head cable connector
For connecting the Scan Head cable that also connects to the Easyscan 2 Controller.

Ground connector
For connecting a cable that puts the sample or the Sample Holder at the same ground potential as the scan head.

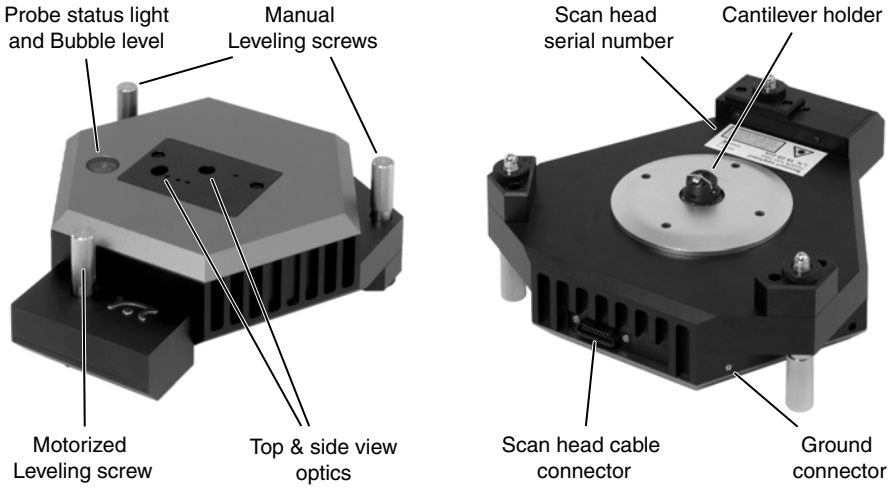


Figure 1-3: Parts of the Scan Head.

Cantilever holder with alignment chip
Used for mounting the cantilever on the scan head (*Section 3.3: Installing the cantilever* (page 33)).

Scan Head serial number
Shows what serial number and version of the scan head you have.

1.3.2: The Easyscan 2 Controller

Status lights

All status lights on top of the controller will light up for one second when the power is turned on.

The Probe Status light
Indicates the status of the Z-feedback loop. The Probe Status light can be in any of the following states:

– **Red**
The scanner is in its upper limit position. This occurs when the tip–sample interaction is stronger than the Setpoint for some time. There is danger of damaging the tip due to an interaction that is too strong.

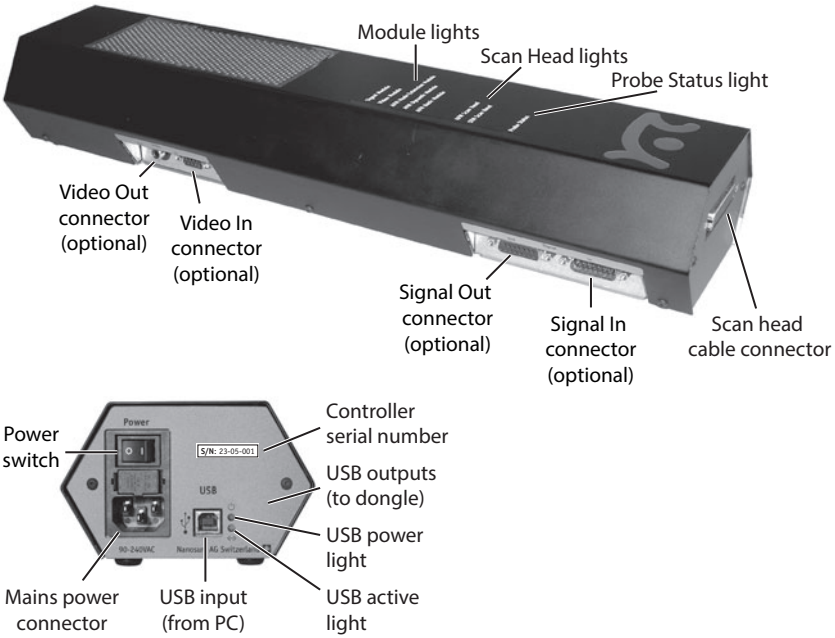


Figure 1-4: The Easyscan 2 controller

– **Orange/yellow**
  The scanner is in its lower limit position. This occurs when the tip–sample interaction is weaker than the Setpoint for some time. The tip is probably not in contact with the sample surface.
– **Green**
  The scanner is not in a limit position, and the feedback loop is able to follow the sample surface.
– **Blinking green**
  The feedback loop has been turned off in the software.
– **Blinking red**
  There is no laser signal to do feedback with (see *Section 17.3.1: Probe Status light blinks red* (page 277) for possible causes and for more information on how to resolve this situation).

The Scan Head lights

Indicate the Scan Head type that is connected to the instrument. The Scan Head lights blink when no Scan Head can be detected, or when the controller has not been initialized yet.

The Module lights
Indicate the modules that are built in into the controller. The module lights blink when the controller has not been initialized yet. During initialization, the module lights are turned on one after the other.

1.3.3: The FlexAFM sample stage

Your FlexAFM system comes with its own sample stage (see *Figure 1-5: The FlexAFM Sample Stage*). The sample stage assists with sample positioning and approach, through a high-quality Z-axis adjustment and easy sample access.

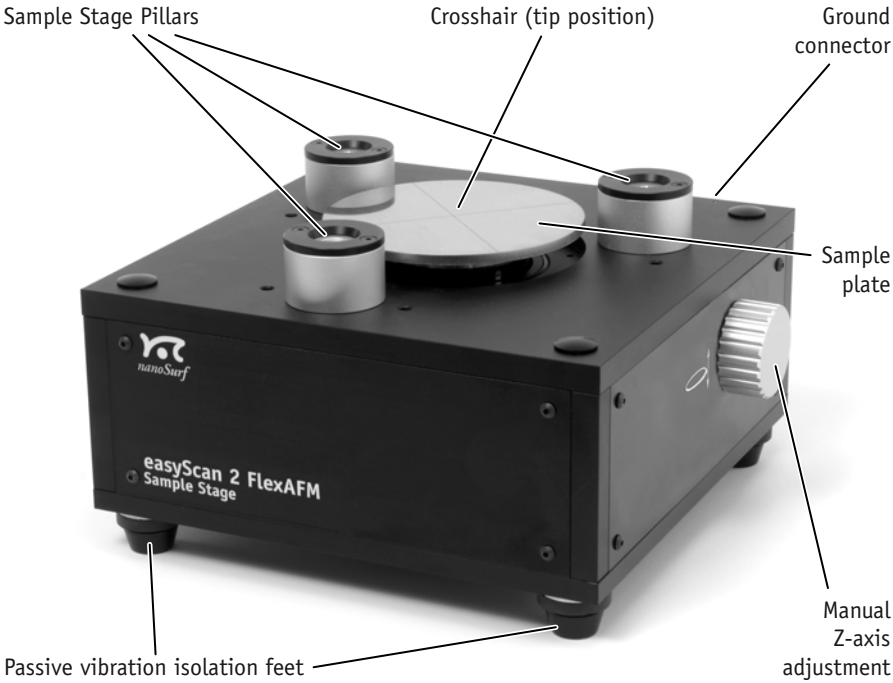


Figure 1-5: The FlexAFM Sample Stage

CHAPTER 2:

Installing the FlexAFM

2.1: Installing the SPM Control Software

2.1.1: Preparations before installing

Before installation, the following steps need to be performed:

1. Make sure the computer to be used meets the minimal computer requirements, as described in *Chapter 19: Technical data* under *Computer requirements* (page 292).
2. Make sure none of the FlexAFM system's hardware is connected to the computer (this includes the (USB) FlexAFM Video Camera).
3. Turn on the computer and start Windows.
4. Log on with Administrator privileges.

IMPORTANT

Do not run any other programs while installing the Easyscan 2 software.

2.1.2: Initiating the installation procedure

To initiate the installation procedure:

1. Insert the Easyscan 2 Installation CD into the CD drive of the computer.

   In most cases, the Autorun CD Menu program will open automatically. Depending on your Autoplay settings, however, it is also possible that the Autoplay window opens, or that nothing happens at all. In these cases:

   - Click "Run CD_Start.exe" in the Autoplay window, or manually open the Easyscan 2 Installation CD and start the program "CD_Start.exe".

IMPORTANT

The Easyscan 2 Installation CD contains calibration information (.hed files) specific to your instrument! Therefore, always store (a backup copy of) the CD delivered with the instrument in a safe place.

2. Click the "Install Easyscan 2 Software" button.

   The CD Menu program now launches the software setup program, which will start installation of all components required to run the Nanosurf Easyscan 2 software.

   In Windows Vista/7, the User Account Control (UAC) dialog may pop up after clicking the "Install Easyscan 2 Software" button, displaying the text "An unidentified program

wants access to your computer". If the name of the program being displayed is "Setup.exe":

➔ Click the "Allow" button.

After the software setup program has started:

❶ Click "Next" in the "Welcome", "Select Destination Folder", and "Select Start Menu Folder" windows that sequentially appear, accepting the default choices in all dialogs.

❷ When the "Ready to install" window appears, click on the "Install" button.

The setup program now performs its tasks without any further user interaction. Depending on the configuration of your computer, a reboot may be required at the end of the software installation process. If this is the case, the setup program will inform you of this, and will provide you with the opportunity to do so.

This completes the driver and control software installation procedure. If you wish to use the Lithography features of the Easyscan 2 software and want to design your own vector graphics for import into the lithography module, you can opt to install the LayoutEditor software by clicking the "Install CAD Program" button in the CD Menu program. This will launch the LayoutEditor installation program, which will guide you through the CAD program setup. Otherwise, you may exit now by clicking the "Exit" button and continue with *Section 2.2: Installing the hardware* and *Section 2.3: Hardware recognition*.

2.2: Installing the hardware

IMPORTANT

- Make sure that the mains power connection is protected against excess voltage surges.
- Place the instrument on a stable support in a location that has a low level of building vibrations, acoustic noise, electrical fields, and air currents.

IMPORTANT

- Never directly touch the cantilevers tips, nor exert too much force on the Cantilever Deflection System (central part of the disc at the bottom of the Scan Head).
- Ensure that the surface to be measured is free of dust and possible residues.
- Always put the Scan Head in the original packaging material during transport and storage.

2.2.1: Installing the Easyscan 2 controller

1. Connect the USB Cable (*Figure 1-1: Components* (page 17), item 5) to the Easyscan 2 Controller (item 1), but do not connect it to the computer yet.
2. Connect the Scan Head Cable (item 7) to the Easyscan 2 controller but not to the Scan Head (item 2) yet.
3. Connect the Easyscan 2 Controller to the mains power using the Mains Cable (item 6), but do not turn on the controller yet.

Figure 2-1: Measurement setup. Complete FlexAFM system.

2.2.2: Installing the FlexAFM Video Camera

Mounting the FlexAFM Video Camera

To mount the FlexAFM Video Camera onto the FlexAFM Scan Head:

1. Remove the two screw located on opposing sides of the black inlay of the top cover of the FlexAFM scan Head (*Figure 2-2: Installing the FlexAFM Video Camera*, left, 1), using a 2 mm Allen key.
2. Attach the FlexAFM Video Camera to the top of the FlexAFM Scan Head (see *Figure 2-2: Installing the FlexAFM Video Camera*, left, 2) with the screws present inside the two holes on top of the FlexAFM Video Camera, using a 2 mm Allen key.

3. Connect the Video Camera USB cable to the mini-USB connector on the FlexAFM Video Camera, but DO NOT connect it to the PC yet.
4. Finish all hardware and software installations as described in the remaining sections of this chapter and make sure to perform the hardware recognition procedure (see *Section 2.3: Hardware recognition*).
5. Return here for the FlexAFM Video Camera image centering procedure outlined below.

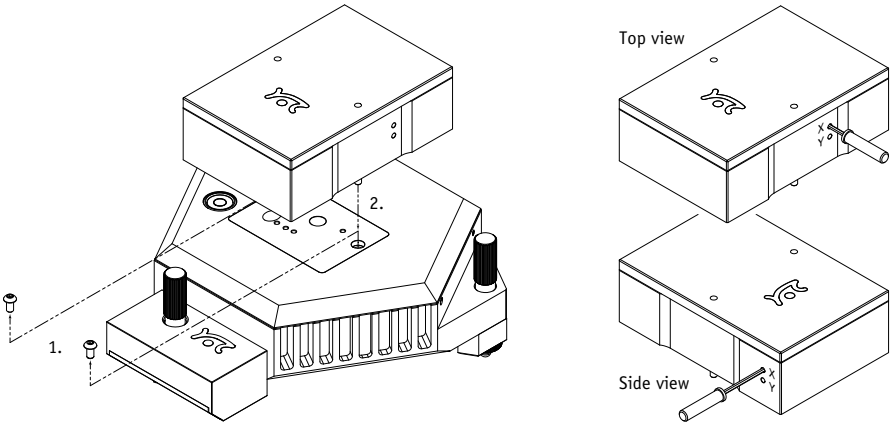


Figure 2-2: Installing the FlexAFM Video Camera. (Left) Mounting the camera. (Right) Centering the video images.

Centering the FlexAFM Video Camera images

To center the top and side view images provided by the FlexAFM Video Camera:

1. Start the SPM Control Software by selecting "Programs" >> "Nanosurf Easyscan 2" >> "Nanosurf Easyscan 2" from the Windows Start menu.
2. Open the top view via the Video panel (see *Section 9.2: Video panel* (page 128)).
3. Use the 1.5 mm Allen key with ball point hex and screwdriver handle (*Section 1.2.1: Contents of the Tool Set* (page 18), item 5) to adjust the center position of the top view (see *Figure 2-2: Installing the FlexAFM Video Camera*, top right).
4. Open the side view via the Video panel (see *Section 9.2: Video panel* (page 128)).
5. Use the 1.5 mm Allen key again to adjust the center position of the side view (see *Figure 2-2: Installing the FlexAFM Video Camera*, bottom right).

2.2.3: Installing the Signal Module A

To install the Signal Module A:

1. Connect one Signal Module cable (*Figure 1-1: Components* (page 17), item 15) to the Signal Out connector on the Controller and to the Output connector on the Signal Module A Connector Box.
2. Connect the other Signal Module cable to the Signal In connector on the Controller and to the Input connector on the Signal Module A Connector Box.

In case of an upgrade, the Easyscan 2 Controller must be sent in to your local Nanosurf distributor for installation of the Signal Module A electronics in the controller housing.

2.2.4: Installing the FlexAFM Scan Head

⚠ WARNING

Never remove the lens cover from the Scan Head (nor remove the built-in top and side view lenses from the lens cover itself), as this would remove the optical filters that block back-reflected laser radiation and protect your eyes from laser damage.

To mount the Scan Head onto the Sample Stage:

1. Make sure that the height-adjustable Sample Plate with Sample Holder and any installed sample is well below the level where the cantilever will be during measurements.
2. Take the Scan Head in both hands and lower it onto the Sample Stage.
   The three Leveling Screws should fit stably into the holes of the Sample Stage Pillars.

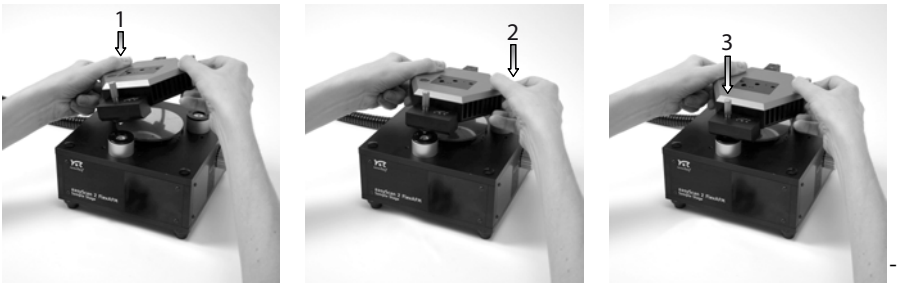


Figure 2-3: Mounting the scan head. It is recommended to always lower the scan head onto the Sample Stage with the Leveling Screws touching the Sample Stage in the same order (numbers in the above pictures). Make sure that the front Leveling Screw (which is used for manual fine approach and automatic final approach) comes last.

CAUTION

- If you use the FlexAFM scan head with an existing Easyscan 2 controller, make sure that the controller contains the Liquid Ready Upgrade. A failure to do so will cause severe damage to the FlexAFM scan head and to the controller electronics. An upgraded Easyscan 2 controller can be recognized by the presence of the "Upgrade installed" label at the bottom of the controller.
- If you own a regular Easyscan 2 AFM scan head in addition to the FlexAFM scan head, make sure to use the proper scan head cable for each scan head. A failure to do so will cause severe damage to the respective scan head and to the controller electronics. The two scan head cables can be distinguished by the presence (FlexAFM) or absence (AFM) of a "FlexAFM" label on the controller-side connector.

❸ Attach the Scan Head cable (*Figure 1-1: Components* (page 17), item 7) to the Scan Head (*Figure 1-1: Components* (page 17), item 2) using the screwdriver (*Figure 1-2: Contents of the Tool set* (page 18), item 4).

It is recommended to cover the instrument in order to shield it from near-infrared light from artificial light sources, since this light may cause noise in the cantilever deflection detection system. The optional Nanosurf Acoustic Enclosures are optimized for this task, and additionally protects against noise and electrical interferences.

If the vibration isolation of your table is insufficient for your measurement purposes, use an active vibration isolation table such as the Nanosurf Isostage or the Halcyoncis_i4. Refer to the respective manuals for installation instructions.

2.3: Hardware recognition

To initiate the automatic hardware recognition process for the devices present in your system:

1. Install all hardware as described in *Section 2.2: Installing the hardware*.
2. Power on the Easyscan 2 controller.
3. Connect the Easyscan 2 controller to the computer with the supplied USB cable (*Figure 1-1: Components* (page 17), item 5). If you own a FlexAFM Video Camera, do not connect it yet.

   A popup balloon appears in the Windows notification area, stating that new hardware devices have been found and drivers are being installed. Depending on the configuration of your controller and computer, the detection process can take quite some time (20 seconds or more). Please be patient! After successful automatic installation, the popup balloon indicates that the installation has finished and that the devices are now ready for use.
4. If you own a FlexAFM Video Camera, it is now time to connect it to a USB port on your computer.

   On Windows 7 computers, a popup balloon in the Windows notification area may display the message "Problem installing driver". If this happens:

   ➔ Disconnect and reconnect the video camera once more.

   Hardware recognition will now complete successfully.

IMPORTANT

- Always connect the FlexAFM Video Camera to a USB port on your personal computer. The use of USB ports that are mounted directly onto the motherboard (usually located at the backside of the PC) is highly recommended. Ports that are not mounted directly (USB ports located at the front of the PC) can cause noise and sync errors due to the sometimes poor quality of cables and connections.
- Do not use the USB hub inside the Easyscan 2 controller (if present), as it does not have sufficient power. The latter will lead to unstable behavior of the video camera and to erratic results.

5.

CHAPTER 3:

Preparing for measurement

3.1: Introduction

Once the system has been set up (see *Chapter 2: Installing the FlexAFM* (page 23)), the instrument and the sample have to be prepared for measurement. The preparation consists of three steps: *Initializing the Easyscan 2 Controller*, *Installing the cantilever*, and *Installing the sample*.

3.2: Initializing the Easyscan 2 Controller

To initialize the Easyscan 2 controller:

1. Make sure that the Easyscan 2 controller is connected to the mains power and to the USB port of the control computer.
2. Turn on the power of the Easyscan 2 controller.

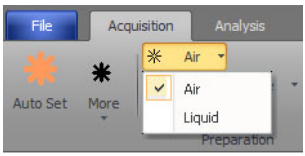
   First all status lights on top of the controller briefly light up. Then the Scan Head lights and the lights of the detected modules will start blinking, and all other status lights turn off.
3. Start the SPM Control Software on the control computer.

   The main program window appears, and all status lights are turned off. Now a Message "Controller Startup in progress" is displayed on the computer screen, and the module lights are turned on one after the other. When initialization is completed, a Message "Starting System" is briefly displayed on the computer screen, and the Probe Status light, the Scan Head status light of the detected scan head, and the Module lights of the detected modules will light up. If no scan head is detected, both Scan Head Status lights blink.
4. In the Preparation group of the Acquisition tab you will see the currently selected Measurement environment, Operating mode and Cantilever type.
5. Determine which measurement environment you wish to use.

   Available options are "Air" and "Liquid".

   To change the measurement environment:

   - Select the measurement environment from the Measurement environment drop-down menu by clicking the currently selected measurement environment:

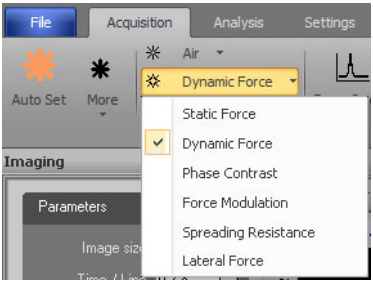


6. Determine which operating mode you wish to use.

   Refer to *Chapter 6: Operating modes* (page 66) for the properties of the modes available.

   To change the operating mode:

   - Select the desired operating mode from the Operating mode drop-down menu by clicking the currently selected operating mode:

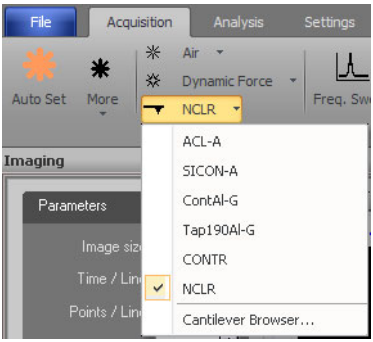


7. Determine which cantilever type you wish to use.

   The cantilever suited for your measurements will depend on Measurement environment, the selected Operating mode and on your sample.

   To change the cantilever type:

   - Select the desired cantilever type from the Cantilever type drop-down menu by clicking the currently selected cantilever type:



3.3: Installing the cantilever

To maximize ease of use, the FlexAFM is designed in such a way that the cantilever can quickly be installed and removed without having to re-adjust the cantilever deflection detection system. The quick cantilever installation is possible because of a Cantilever Holder that can be removed from the Scan Head (*Figure 3-4: Replacing a cantilever*, left), and

because this Cantilever Holder contains a self-alignment system. The alignment system consists of a structure in the alignment chip and matching grooves in the back side of the cantilever chip. The alignment system positions the cantilever with micrometer accuracy (see *Figure 3-1: Cantilever,* left). This accuracy is only guaranteed when the cantilever and the mounting chip are absolutely clean. Installation of the cantilever should therefore still be carried out with great care. The quality of measurements depends strongly on the accuracy of the installation.

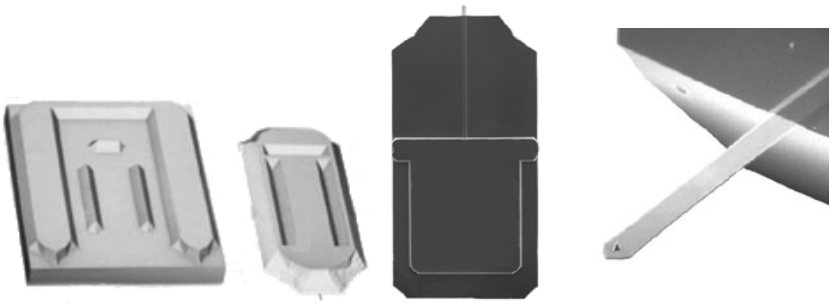


Figure 3-1: Cantilever. (Left) Alignment system. (Center) Cantilever chip viewed from the top. (Right) Cantilever, 450 µm long, 50 µm wide with integrated tip.

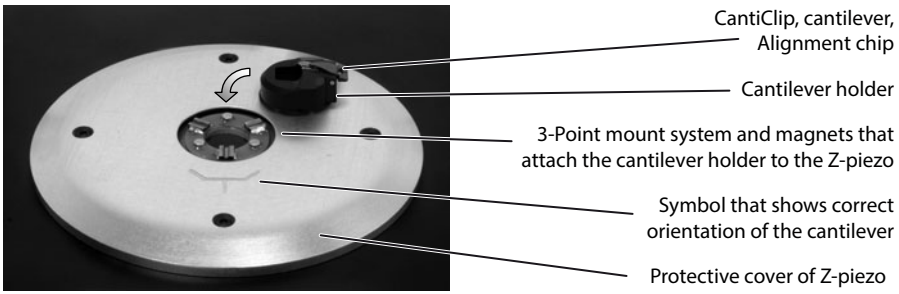


Figure 3-2: Cantilever deflection detection system

3.3.1: Selecting a cantilever

It is very important that the cantilever type is suitable for the operating mode that is used. Stiffer and shorter cantilevers (e.g. NCLR [Nanoworld] or Tap190Al-G [BudgetSensors]) are generally used for the Dynamic operating mode. More flexible and longer cantilevers (e.g. CONTR [Nanoworld] or ContAl-G [BudgetSensors]) are generally used for the Static operating mode.

To change to a different cantilever type:

➔ In the Preparation group of the Acquisition tab, select the desired cantilever type from the "Mounted cantilever" drop-down menu by clicking the currently selected cantilever type.

The various usable types are listed in *Section 19.2.1: Specifications and features* (page 288), under *Compatible cantilevers*.

3.3.2: Removing the Cantilever Holder

If you are working with the Nanosurf FlexAFM system for the first time, the Cantilever Holder will not be attached to the Scan Head yet. In this case, you may continue with *Section 3.3.3: Inserting the cantilever in the Cantilever Holder*.

In case you have used the system before and the Cantilever Holder is attached to the Scan Head, it first needs to be detached.

To remove the Cantilever Holder from the Scan head:

1. Make sure the sample is away far enough from the Scan head (see *Section 6.1: Finishing scanning* (page 70)).
2. Lift up the Scan head with both hands (front side first, followed by each of the two back sides, as in *Figure 3-3: Removing the Cantilever Holder*, left).
3. Turn the scan head to one side, firmly holding it in one hand (*Figure 3-3: Removing the Cantilever Holder*, left center).

   When the scan head is tilted sideways 90 degrees or more, the laser is automatically turned off to protect the user's eyes.
4. Use your other hand to remove the Cantilever Holder (*Figure 3-3: Removing the Cantilever Holder*, right center), and place it on top of the Cantilever Exchange Tool.
5. Put the Scan head back onto the Sample Stage (*Figure 3-3: Removing the Cantilever Holder*, right).

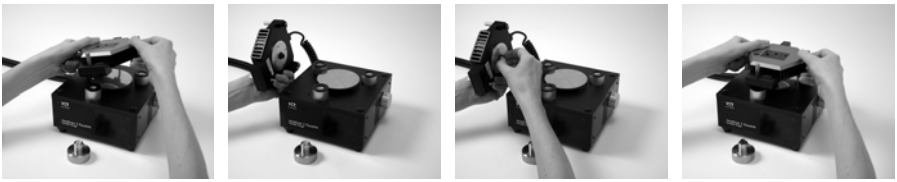


Figure 3-3: Removing the Cantilever Holder

3.3.3: Inserting the cantilever in the Cantilever Holder

CAUTION

- Nothing should ever touch the cantilever.
- The Cantilever Holder Spring (see *Figure 3-4: Replacing a cantilever*) is very delicate. NEVER overstretch it! It will become bent and unusable otherwise!
- Never close the CantiClip without a cantilever installed, as this would damage the alignment chip.

To remove the old cantilever:

1. Use the Cantilever Tweezers or your finger to push onto the wide end of the CantiClip (*Figure 3-4: Replacing a cantilever*, top left).
2. Gently push down until the CantiClip flips to its open position (*Figure 3-4: Replacing a cantilever*, top center).
3. Use the Cantilever Tweezers to remove the old cantilever from the Cantilever Holder (*Figure 3-4: Replacing a cantilever*, top right).

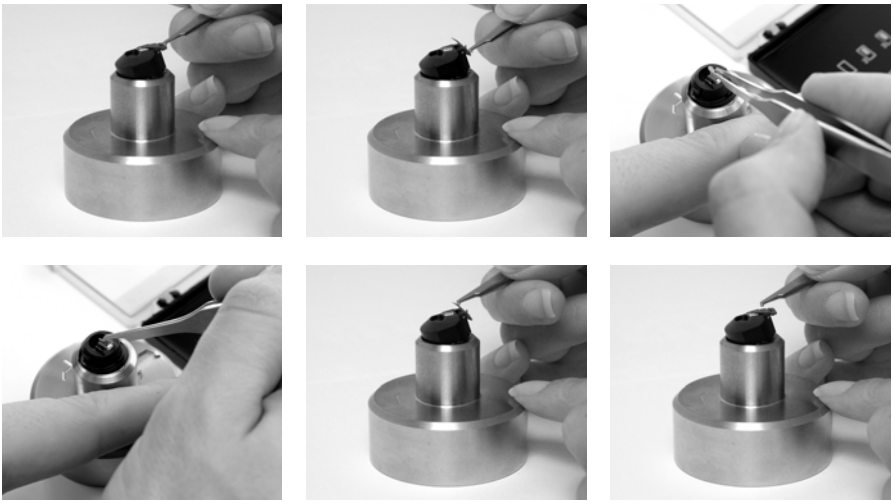


Figure 3-4: Replacing a cantilever. (Top) removing the old cantilever, (Bottom) mounting the new cantilever.

In case the previous measurement was performed in liquid (Cantilever Holder Liquid/Air), the cantilever (if it is to be re-used) and the Cantilever Holder need to be cleaned first. To do this:

1. Carefully remove most excess liquid from the cantilever and Cantilever Holder with a piece of paper.

   If the Cantilever Alignment Chip is really dirty, you can clean it with mild dish soap, followed by rinsing with clean water.

IMPORTANT

Although it is OK for the inside of the Cantilever Holder to get wet, no deposits should be allowed to form. Therefore, blow-dry the Cantilever Holder as soon as possible!

2. Use a (compressed gas) air duster to blow-dry the cantilever and Cantilever Holder.

To insert the new cantilever:

1. Take the new cantilever out of its box with the cantilever tweezers.
2. Place the cantilever carefully on the alignment chip (*Figure 3-4: Replacing a cantilever*, top right).
3. Verify that the cantilever does not move with respect to the Alignment Chip by carefully tapping on it with the tweezers (*Figure 3-4: Replacing a cantilever*, bottom left).

   If the cantilever does move, it is probably not inserted correctly. Refer to *Figure 3-5: Cantilever Alignment* for correct alignment and examples of incorrect alignment.

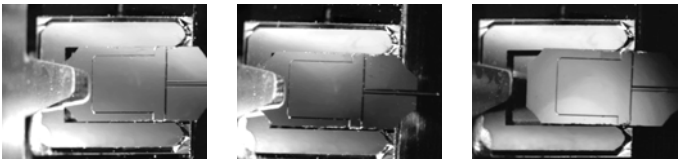


Figure 3-5: Cantilever Alignment. (Left) correct: the mirrored environment shows a reflection that is continuous over the cantilever and the alignment chip, and small triangular gaps can be seen between the edges of the alignment chip and the corners of the cantilever chip, (center & right) incorrect: the mirrored environment shows a reflection that is different on the cantilever and on the alignment chip, and no nice triangular gaps can be discerned.

4. Use the cantilever tweezers or your finger to gently push on the narrow end of the CantiClip (*Figure 3-4: Replacing a cantilever*, bottom center image).

   The CantiClip snaps into its closed position and firmly holds the cantliever in place (see *Figure 3-4: Replacing a cantilever*, bottom right). The cantilever is now securely attached and aligned.

3.3.4: Attaching the Cantilever Holder to the Scan Head

To attach the Cantilever Holder with newly installed cantilever to the Nanosurf FlexAFM Scan Head:

1. Pick up the scan head with two hands (*Figure 3-6: Attaching the Cantilever Holder*, left).
2. Turn the scan head to one side, firmly holding it in one hand (*Figure 3-6: Attaching the Cantilever Holder*, left center).

   When the scan head is tilted sideways for 90 degrees or more, the laser is automatically turned off to protect the user's eyes.
3. Pick up the Cantilever Holder from the Cantilever Exchange Tool with your other hand, and bring the Cantilever Holder near the Scan Head Deflection System (in the center of the metal disc on the bottom of the Scan Head) to allow it to snap on (*Figure 3-6: Attaching the Cantilever Holder*, right center).

   Three Magnets pull the Cantilever Holder firmly in place. A 3-point mount system provides exact alignment.
4. Place the Scan Head back on top of the Sample Stage (*Figure 3-6: Attaching the Cantilever Holder*, right).

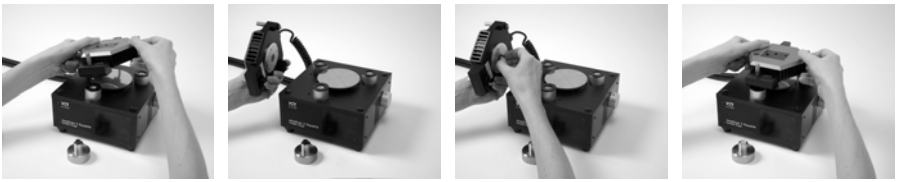


Figure 3-6: Attaching the Cantilever Holder

3.4: Installing the sample

3.4.1: Preparing the sample

The FlexAFM can be used to examine any material with a surface roughness that does not exceed the height range of the scanning tip. Nevertheless the choice and preparation of the surface can influence the surface–tip interaction. Examples of influencing factors are

excess moisture (during measurements in air), dust, grease or other contaminations of the sample surface. Because of this, some samples need special preparation to clean their surface. Generally, however, only clean your samples if this is absolutely required, and be sure to clean very carefully in order not to harm the sample surface. Some contaminations may go away without any further cleaning when performing measurements in liquid. You may consider trying this instead of cleaning.

If the surface is dusty, try to measure on a clean area between the dust. Although it is possible to blow away coarse particles with dry, oil-free air, small particles generally stick quite strongly to the surface and cannot be easily removed this way. Also note that bottled, pressurized air is generally dry, but pressurized air from an in-house supply is generally not. In this case an oil filter should be installed. Blowing away dust by breath is not advisable, because the risk of contaminating the sample even further is very high.

When the sample surface is contaminated with solid matter or substances that can be dissolved, the surface should be cleaned with a solvent. Suitable solvents are distilled or demineralized water, alcohol or acetone, depending on the nature of the contaminant. The solvent should always be highly pure in order to prevent accumulation of impurities contained within the solvent on the sample surface. When the sample is very dirty, it should be cleaned several times to completely remove partially dissolved and redeposited contaminants. Delicate samples, which would suffer from such a treatment, can alternatively be cleaned in an ultrasonic bath.

3.4.2: Nanosurf samples

Nanosurf delivers various optional samples, which are usually packed in the FlexAFM Tool Set. These samples are briefly described here. Further samples are available in the AFM Extended Sample Kit, which contains its own sample description.

All samples should be stored in their respective box. This way, it should not be necessary to clean them. Cleaning of the samples is generally not advisable (unless indicated below), because their surfaces are often rather delicate.

Grid: 10 µm / 100 nm

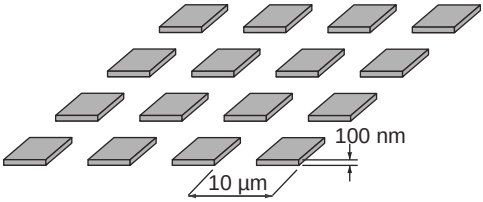


Figure 3-7: Structure of Grid: 10 µm / 100 nm

The Grid: 10 µm / 100 nm can be used for testing the XY-calibration of the 70 µm and 100 µm scanners, and for testing the Z-calibration. It is manufactured using standard silicon microfabrication technology, which produces silicon oxide squares on a silicon substrate. It has a period of 10 µm and a square height of approximately 100 nm.

Sample specifications:

Size:	5 mm × 5 mm
Material:	Silicon oxide on silicon
Structure:	Square array of square hills of silicon oxide hills on silicon.
Grid period:	10 µm
Approximate height:	100 nm

Calibrated values of period and height (with 3% accuracy) are printed on the package. Certified Calibration grids are available as an option.

Grid: 660 nm

The Grid: 660 nm can be used to test the XY-calibration of the 10 µm scanner. Depending on the grid version, it consists either of:

- Silicon oxide hills on a silicon substrate with a period of 660 nm and an unspecified height. The approximate height is 149 nm,
- Holes in a silicon oxide layer with a period of 660 nm and an unspecified depth. At the time of writing, the approximate depth is 60 nm.

Sample specifications:

Size:	5 mm × 5 mm
Material:	Silicon oxide on silicon
Structure:	Square array of holes or hills in the silicon oxide layer
Period:	660 nm. Calibrated value of period (with 3% accuracy) is printed on the package. Certified Calibration grids are available as an option.

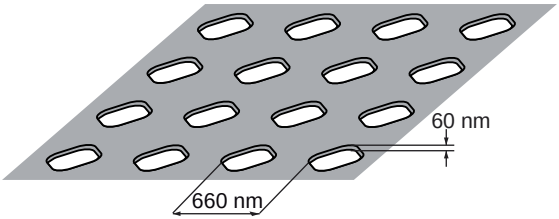


Figure 3-8: Structure of Grid: 660nm (version with holes)

Flatness sample

The Flatness sample is a polished silicon sample. It can be used for testing the Flatness of the scanned plane.

Sample specifications:

Size:	5 mm × 5 mm
Material:	Silicon
Thickness:	Approx. 320 µm

CD-ROM piece

Sample for demonstrating the AFM imaging. The CD sample is a piece from a CD, without any coating applied to it.

Sample specifications:

Material:	Polycarbonate
Structure:	100 nm deep pits arranged in tracks that are spaced 1.6 µm apart.

Microstructure

Sample for demonstrating AFM imaging (no longer available). The microstructure is approximately the negative of the Grid: 10µm / 100nm. It consists of holes in a silicon oxide

layer with an unspecified period and depth. The approximate period is 10 µm, the approximate depth is 100 nm.

Graphite (HOPG) on sample support

This sample can be used for STM as well as AFM measurements. In high resolution AFM measurements, the atomic steps of the graphite surface can be seen. Conductivity variations can be observed in Spreading Resistance mode.

Sample specifications:

Size:	5 mm × 5 mm
Material:	Highly Oriented Pyrolytic Graphite (HOPG)
Sample support:	Teflon on Magnetic Steel disc

The surface of the graphite sample can be cleaned when it is very dirty or uneven. Due to the layered structure of graphite this can easily be done using a piece of adhesive tape (*Figure 3-9: Cleaving graphite*):

1. Put the sample on the table using a pair of tweezers.
2. Stick a piece of adhesive tape gently to the graphite and then pull it off again. The topmost layer of the sample should stick to the tape.
3. Remove any loose flakes with the tweezers.

The graphite sample is now ready for use and should not be touched anymore.

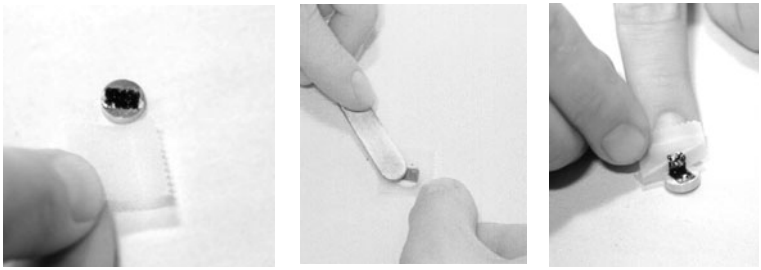


Figure 3-9: Cleaving graphite

3.4.3: The Sample Stage

The Sample Stage (*Figure 1-1: Components* (page 17), item 8) offers vibration isolation and reproducible scan head placement (see *Figure 3-10: The FlexAFM Scan Head on its Sample Stage*) and can be used to comfortably position a sample. An optional Micrometer Translation Stage for XY-positioning can be mounted on the Sample Stage. The sample

should be mounted onto the Sample Holder (*Figure 1-2: Contents of the Tool set* (page 18), item 6) before measurement (see *Section 3.4.4: Mounting a sample*).

CAUTION

To avoid damage to the cantilever, make sure that the top of the sample is well below the top level of the Sample Stage Pillars before mounting the Scan Head. If necessary, turn the manual Z-axis adjustment knob counterclockwise to adjust to a lower position.

Figure 3-10: The FlexAFM Scan Head on its Sample Stage

3.4.4: Mounting a sample

Samples may either be placed directly onto the sample stage, or first mounted onto the Sample Holder before being placed there.

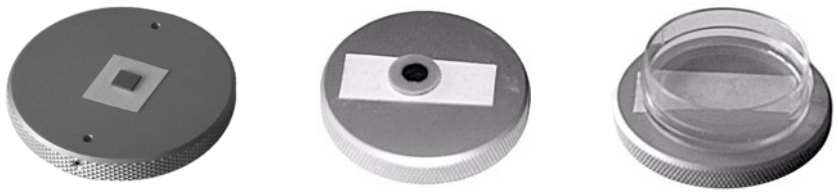


Figure 3-11: Samples mounted onto the Sample Holder

To mount a sample onto the Sample Holder:

1. Put a double-sided adhesive tape on the frontside of a Post-it® note, so that it is on the opposite side of the sticky part.
2. Cut off all parts of the note that do not have adhesive tape on it.
3. Fix the tape-side of the prepared note to the Sample Holder.
4. Put the sample on the sticky side of the Post-it® note, and press on it lightly.

   The result should resemble *Figure 3-11: Samples mounted onto the Sample Holder*, left. When performing measurements in liquid, use teflon/steel discs to first securely glue the sample to, before putting the glued sample and disc onto the sample holder (*Figure 3-11: Samples mounted onto the Sample Holder*, center). Alternatively, use samples (e.g. living or fixed cells) in Petri dishes or other liquid containers to directly perform measurements in liquid (*Figure 3-11: Samples mounted onto the Sample Holder*, right).
5. Lower the sample platform by turning the manual Z-axis adjustment knob counterclockwise, and place the Sample Holder on top of the Sample plate.

   It is recommended to always connect the Sample Holder to the ground connector on the Scan Head using the ground cable.
6. When using Teflon/steel discs to measure in liquid, add 50–60 µl of water or a suitable buffer on top of your sample using a pipette.
7. Raise the sample platform by turning the manual Z-axis adjustment knob clockwise, but be sure to keep a safe distance between the cantilever and the sample/liquid surface.

CHAPTER 4:

A first measurement

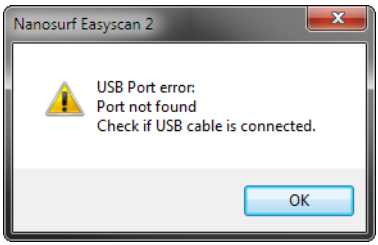
4.1: Introduction

In this chapter, step-by-step instructions are given to operate the microscope and to perform a simple measurement in air and in liquid. More detailed explanations of the software and of the system can be found elsewhere in this manual.

4.2: Running the microscope simulation

The SPM Control Software can be started without having the microscope connected to your computer in order to explore the Easyscan 2 system (measurements and software) without danger of damaging the instrument or the cantilever. In simulation mode, most functions of the real microscope are emulated. The sample is replaced by a mathematical description of a surface.

When the SPM Control Software is started without a microscope connected to your computer, the following dialog appears:



➔ Click “OK”.
The status bar will now display the text “Simulation”.

You can also switch to simulation mode with the microscope connected:

➔ In the Hardware group of the Settings tab, click the “Simulation” button.
The “Simulation” button will now be highlighted and the status bar will display the text “Simulation”.

To exit the microscope Simulation mode:

➔ In the Hardware group of the Settings tab, click the “Simulation” button again.
The highlighting of the “Simulation” button will now disappear, and the status bar will display the text “Online”.

4.2.1: Entering and changing parameter values

When using the Nanosurf FlexAFM and SPM control software, you may from time to time need to change or enter parameter values. These can be found in the parameter sections of the Operating windows and in various dialogs.

To change a parameter or enter a value:

❶ Activate the parameter by clicking inside the (white) parameter edit box with the mouse:

❷ In case of a drop-down menu selection list, change the selection using the mouse or the up and down arrows on the keyboard. In case of a numerical value, use one of the following methods:

- Use the up and down arrow keys on the keyboard to increase or decrease its value. The new value is automatically used after one second.
- Click the arrow buttons next to the parameter value with the mouse pointer. Normally, the parameter value is changed by a small amount (usually in the range of 1–10%). Some edit boxes are doubling or dividing the parameter value by two (e.g. the "points/line" parameter). The new value is automatically used after one second.
- Enter the new value using the keyboard. The entered value is applied upon pressing the "Enter" or "Return" key, or by activating another input. The entered value is discarded upon pressing the "Esc" key. The unit prefix can be changed by typing one of the following keyboard keys:

f = femto		space bar	= no prefix
p = pico		k	= kilo
n = nano		M (shift-m)	= mega
u = micro		G (shift-g)	= giga
m = milli		T (shift-t)	= tera

Examples: if the basic unit is Volts, type "m" to change to millivolts, type the space bar for volts, type "u" for microvolts.

Sometimes the program will change an entered value to a slightly different value. This happens when the desired value is outside the digitization range of the Easyscan 2 controller, for example due to resolution or timing limits. In such cases, the desired value is automatically changed to the nearest possible value.

When you are finished with the microscope simulation you are now ready to use the FlexAFM scan head for measurements.

4.3: Preparing the instrument

IMPORTANT

- Never touch the cantilever or the surface of the sample! Good results rely heavily on a correct treatment of the tip and the sample.
- Avoid exposing the system to direct light while measuring. This could influence the cantilever deflection detection system and reduce the quality of the measurement.

Prepare the instrument as follows (see *Chapter 3: Preparing for measurement* (page 31) for more detailed instructions):

❶ If your Easyscan 2 Controller has Dynamic measurement capabilities, install an NCLR type cantilever. Otherwise install a CONTR type cantilever.

❷ Install one of the samples from the Nanosurf AFM Basic Sample Kit or Calibration Sample Kit. Preferably, install the 10 µm Calibration grid.

The measurement examples shown here were made with the 10 µm Calibration grid.

To make sure that the configuration is correct, do the following:

➔ Open the menu item "File" >> "Parameters" >> "Load..." and load the file "Default_FlexAFM.par" from the directory that holds the default Easyscan 2 configurations.

Usually this is "C:\Program Files\Nanosurf\Nansurf Easyscan 2\Config".

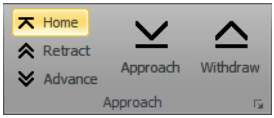
4.4: Approaching the sample

To start measuring, the cantilever tip must come within a fraction of a nanometer of the sample without touching it with too much force. To achieve this, a very careful and sensitive approach of the cantilever is required. This delicate operation is carried out in three steps: *Manual coarse approach using the FlexAFM Sample Stage*, *Manual fine approach using the leveling screws*, and the *Automatic final approach*. The color of the Status lights on the controller and on the scan head show the current status of the approach:

– **Orange/yellow**
  Normal state during approach: the Z-scanner is fully extended toward the sample.
– **Red**
  The approach has gone too far: the tip was driven into the sample, and the Z-scanner is fully retracted from the sample. In this case, the tip is probably damaged and you will have to install a new cantilever again.
– **Green**
  The approach has finished successfully: the Z-scanner is within the measuring range.

To prepare for the approach process:

1. Select the Acquisition tab.
   The controls for positioning the cantilever with respect to the sample are located in the Approach group.
2. Click the "Home" button in the Approach panel to bring the approach motor on the front-most leveling screw of the FlexAFM scan head in its upper position:



   This will ensure that the maximum motorized approach range is available for automatic final approach.

During the approach steps described in the following sections, use the side view of the cantilever to judge the distance between tip and sample surface:

- If the FlexAFM Video Camera is installed, open the Video panel (see *Section 9.2: Video panel* (page 128)) in the Info pane.
  If the Video Camera is not installed, use the side view lens of the scan head to observe the sample instead.

4.4.1: Manual coarse approach using the FlexAFM Sample Stage

In this step, the sample surface is brought close enough to the tip to allow fine-tuning via the leveling screws and automatic motorized approach afterwards.

IMPORTANT

- When approaching a sample in liquid, the cantilever and cantilever holder first have to be brought into contact with the liquid medium, and then submerged into it, to be able to use the microscope's integrated side view of the cantilever. During this process, it is necessary to judge the distance between cantilever tip and sample/liquid surface by watching the system from the side (see *Figure 4-1: View of the manual coarse approach in liquid*).

IMPORTANT

- Upon first contact with the liquid and/or during the initial immersion phase, the status light might start blinking red. This is due to the fact that the space between cantilever and cantilever holder optics has not yet completely filled with liquid, and the laser beam therefore doesn't reach the detector. This problem is resolved by moving the cantilever into the liquid environment a little bit further. The status light will then return to its normal orange/yellow state. From this point on, the side view of the microscope can be used to better judge the tip–sample distance.

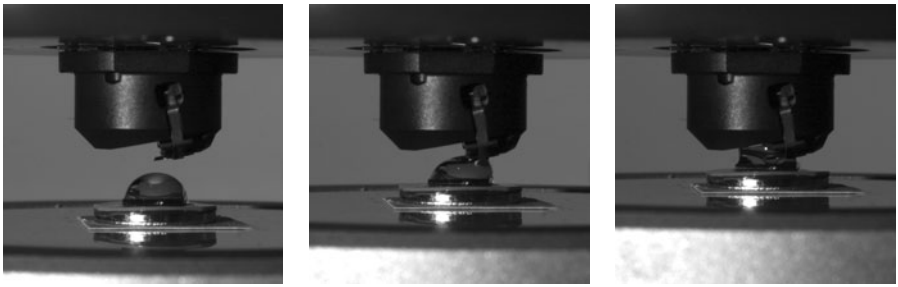


Figure 4-1: View of the manual coarse approach in liquid. (Left) Out of contact; the status light is orange/yellow. (middle) Partial contact; the status light usually starts blinking red. (Right) Meniscus formed; the entire space between sample, cantilever, and cantilever holder optics is filled with liquid, and the SureAlign laser optics inside the cantilever holder assure perfect alignment of the laser beam. The status light switches to a constant orange/yellow again.

To perform a manual coarse approach:

❶ Use the leveling screws to bring the scan head in a position that is approximately parallel to the sample surface.

❷ Slowly turn the manual Z-axis adjustment knob on the FlexAFM sample stage clockwise to bring the sample surface to within 1 mm of the cantilever tip.

The side view should now look as shown in *Figure 4-2: Side view of the cantilever after manual coarse approach*. When the sample is reflective, the mirror image of the cantilever should be visible. When the sample is not reflective, the shadow of the cantilever may be visible. If neither a mirror image nor a shadow is visible, change the environment light until it is. You can use the cantilever as a ruler to judge distances in the views of the integrated optics.

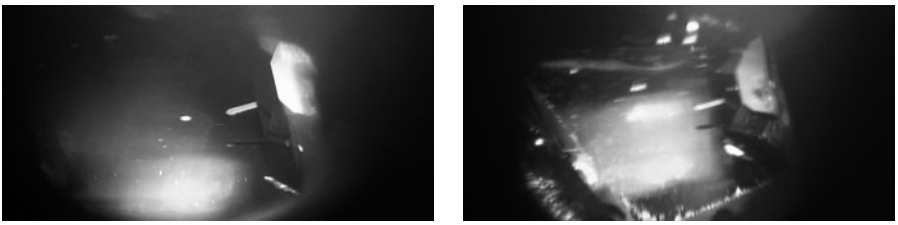


Figure 4-2: Side view of the cantilever after manual coarse approach. (Left) in air, (Right) in liquid).

4.4.2: Manual fine approach using the leveling screws

In this step, the tip is brought as close to the sample surface as possible, without touching it. The closer the two are together, the less time the automatic final approach takes.

1. Observe the distance between tip and sample in the side view of the integrated optics.
2. While observing the tip–sample distance, slowly turn the leveling screws counterclockwise until the tip is close enough to the sample.

   Use all leveling screws to ensure that the scan head remains parallel to the sample surface. The tip should not come closer to the sample than a few times the cantilever width (see *Figure 4-3: View of cantilever after manual fine approach using the leveling screws*, left).

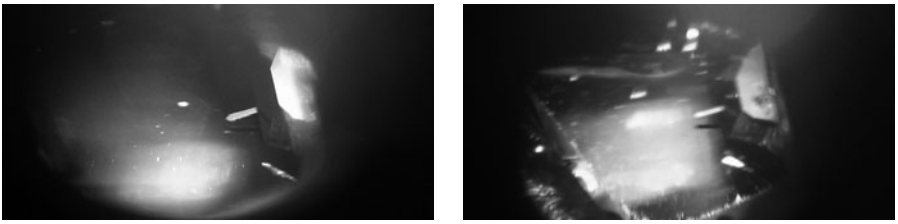


Figure 4-3: View of cantilever after manual fine approach using the leveling screws. (Left) in air, (Right) in liquid.

Now that the sample is in focus, the top view image can be used to find a suitable location to measure on. In top view, the sample is seen from a direction perpendicular to its surface (see *Figure 4-4: Top view of cantilever and sample*.

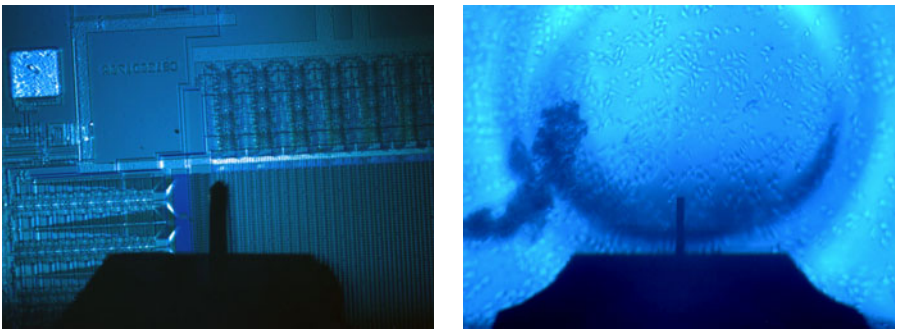


Figure 4-4: Top view of cantilever and sample. (Left) chip structure in air, (Right) cells in liquid.

To use the top view:

1. If the FlexAFM Video Camera is installed, select Top view in the Video panel (see *Section 9.2: Video panel* (page 128)). If the Video Camera is not installed, use the top view lens to observe the sample instead.
2. If necessary, move the Sample Holder to find a suitable location that is free of dust particles.

4.4.3: Automatic final approach

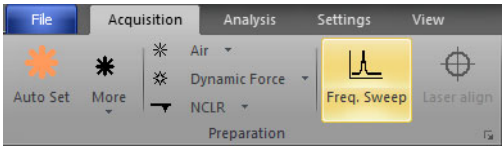
In this last step, the tip automatically approaches the sample until a given Setpoint is reached. Before starting the automatic approach, select the desired operating mode, measurement environment, and cantilever type. To do this:

- In the Preparation group of the Acquisition tab, select an operating mode, measurement environment, and cantilever type that match the cantilever installed.

In Dynamic Force mode, the instrument will automatically determine the vibration frequency to be used during imaging. To determine the optimal frequency, the controller performs a coarse and a fine frequency sweep in which the cantilever vibration amplitude (and — in Phase Contrast mode — also the phase) are recorded as a function of excitation

frequency. It is instructive to see both frequency sweep measurements in all detail at least once. To do this, it is possible to manually perform the frequency sweeps:

1. In the Preparation group of the Acquisition tab, click the "Freq. Sweep" button:



   The Vibration Frequency Search dialog now opens (see *Section 8.13: Vibration Frequency Search dialog* (page 120) for details).

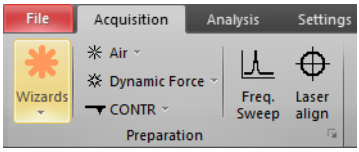
2. Click the "Auto frequency set" button.

   The SPM Control Software now sets appropriate values for the coarse and fine sweeps and performs these sweeps. The fine sweep will overwrite the data of the coarse sweep in the charts displayed in the "Vibration frequency search" dialog. To see the results of the individual sweeps:

   - Press the "Coarse sweep" and "Fine sweep" buttons sequentially.

Before final approach of the sample, it is necessary to set the scanning and feedback parameters of the control software to suitable initial values. The easiest way to do this is to use the Imaging Wizard:

1. In the Preparation group of the Acquisition tab, click the "Wizard" button:



2. Select "Imaging..." from the drop-down selection menu.

   A dialog will pop up, which will ask you some basic questions about your sample and your measurement needs.

3. Answer the questions of the wizard to the best of your knowledge.

   For descriptions of the features of standard Nanosurf samples refer to *Section 3.4.2: Nanosurf samples* (page 39).

Now that the initial software settings have been given suitable values, you need to name the measurement series (see *Section 13.4.1: History File mask* (page 220)). Each completed measurement (scan/image) will be temporarily saved (automatically) in the History folder under this name, with index numbers (or, optionally, date and time attributes) added to identify the individual measurements. It is best to enter the measurement series' name now, since the control software will (by default) start measuring as soon as the final

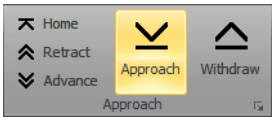
approach is done. It is also strongly recommended to move all relevant measurements to a new folder when you are finished, since the files in the History folder will be overwritten over time (see *Max History Files* (page 248)).

To set the measurement series name:

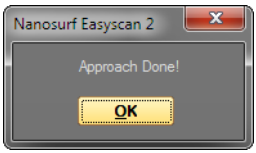
1. Activate the Gallery panel (see *Section 13.4: Gallery panel* (page 219)) in the Info pane.
2. Click the History tab at the top of the Gallery panel with the mouse.
3. In the entry box at the top of the panel, enter a name by hand or use the Mask Editor dialog (see *Section 13.4.4: Mask Editor dialog* (page 221)) to create the name mask.
   If no [INDEX] attribute is explicitly added to the name mask, it will be implicitly applied to the end of the file name so that individual measurements can be stored and distinguished.

The automated final approach can now be started. To do this:

1. In the Approach group of the Acquisition tab, click the "Approach" button:



   The cantilever is moved towards the sample via the approach stage, with the Z-Controller turned on. This movement continues until the Z-Controller error becomes zero. From this point onward, the distance between sample and tip is maintained automatically by the electronics. The probe status light changes to a constant green, and a message "Approach done" appears:



2. Click the "OK" button.

After the automatic final approach, the side view of the cantilever should look something like the ones in *Figure 4-5: View of the cantilever after automatic final approach*

If the automatic final approach fails, refer to *Section 17.3: AFM measurement problems* (page 277) for the next steps to take.

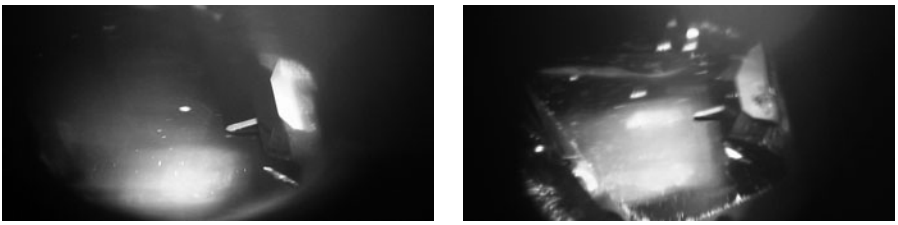
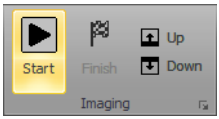


Figure 4-5: View of the cantilever after automatic final approach. (Left) in air, (Right) in liquid.

4.5: Starting a measurement

Now that the tip–sample interaction defined by Setpoint is established between tip and sample, measurements can start. By default, the instrument is set to automatically start measuring after the automatic approach. If this is not the case:

➔ Start measurements manually by clicking the "Start" button in the Imaging group of the Acquisition tab:



Two representations of the ongoing measurement are drawn in the Imaging panel. One representation is a color coded height image (Topography) called a Color map. The other is a plot of height as a function of X* position called a Line graph. With the current settings, the software automatically adjusts the contrast of the Color map, and height range of the Line graph to the data that have been measured.

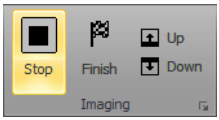
To judge the imaging quality, watch the displays until at least one fourth of the measurement has been completed.

IMPORTANT

Measurements on the micrometer/nanometer scale are very sensitive to environment influences. Direct light or fast movements — causing air flow and temperature variations near the Scan Head — can influence and disturb the measurement.

When a measurement contains large disturbances, or no two scan lines are similar, stop measuring and reduce or eliminate the disturbances. To do this:

➔ Click the "Stop" button in the Imaging group of the Acquisition tab and follow the instructions in *Chapter 17: Problems and solutions* (page 273):



4.6: Selecting a measurement area

If you were able to prepare your measurement so that the scan line in the Line graph reproduces stably, the color map graph should look similar to the one shown below when the measurement has finished.

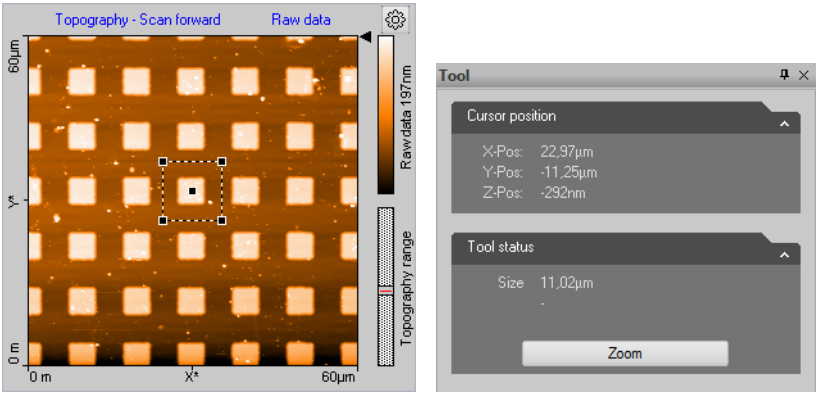
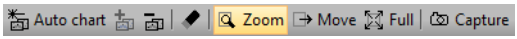


Figure 4-6: Zooming in on an overview measurement

To zoom in to an interesting part of the measurement:

1. Activate the color map graph by clicking on it.
2. Click the "Zoom" button in the Chart bar:

   The mouse pointer becomes pen-shaped when moving over the color map.
3. Click on one corner of the region to be selected using the left mouse button, and keep the button pressed.
4. Drag the mouse to the other corner of the region.

   The size and the position of the square are shown in the Tool results panel of the Info pane.

5. Release the mouse button when the size of the square covers approximately one period of the grid.

6. Confirm the selection by double clicking the color map graph using the left mouse button. Now the selection is enlarged to the whole display size. You can abort the zoom function by clicking the "Zoom" button again.

The microscope will now start measuring a single grid period. Once the measurement is completed, you should get an image such as the one in *Figure 4-7: Zoomed measurement,* left. The depression in the sample surface to the sides of the structure is due to the LineFit data filter used. To remove it, click on "LineFit" and select the data filter "Raw Data" from the drop-down menu. The chart will now look like *Figure 4-7: Zoomed measurement,* right.

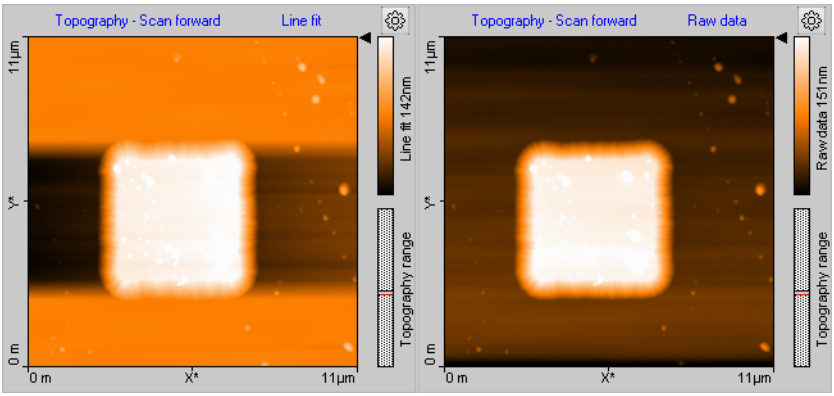
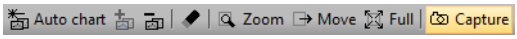


Figure 4-7: Zoomed measurement. (Left) with line subtraction, (Right) without line subtraction.

4.7: Storing the measurement

By default, each completed measurement is temporarily stored (automatically) on your computer so that it can be used later. Additionally, you can also take snapshots of measurements still in progress. To do this:

- Click the "Capture" button in the Chart bar:



The current measurement is immediately stored and will show up in the History page of the Gallery panel, together with all other finished/stored measurements (see *Section 13.4: Gallery panel* (page 219) for details). In addition, the captured document will remain open in the Document space of the SPM Control Software.

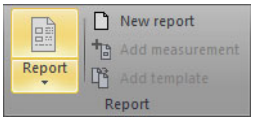
Measurement documents in the temporary History folder should always be moved to a new location for permanent storage when you are done measuring. For details on how to do this, see *Save as* (page 220). Measurement documents thus permanently stored can always be loaded with the SPM Control Software or the optional Nanosurf Report or Nanosurf Analysis software packages for later viewing, analysis, and printing. A brief introduction on how to create a basic report using the Report software is given in the next section. For more detailed information on starting and using the Report software, see *Section 22.2: Creating a report* (page 452), or refer to the Nanosurf Report online help.

4.8: Creating a basic report

The optional Nanosurf Report software can be used to evaluating the measurement, and to create visually appealing reports. Here, we will just briefly explain how to start the software and create a basic report.

To create a basic report of a completed measurement:

1. Open a measurement from the Gallery panel.
2. In the Report group of the Analysis tab, click the "Report" button.



The Nanosurf Report software will now launch, import the currently open measurement, and evaluate the data using the default template.

IMPORTANT

After a fresh installation of the Report software, the Report software has to be run at least once before it can be automatically started from within the SPM Control Software. To run the Report software for the first time, select it from the Microsoft Windows "Start" menu.

4.9: Further options

From this point on, there are several things that can be done. Please refer to the respective chapters for detailed instructions:

- Performing a new measurement on another sample by repeating the instructions given in *Chapter 3: Preparing for measurement* and *Chapter 4: A first measurement* with the new sample.

- Performing a new measurement in a different measurement environment by adding/removing liquid to/from the sample and repeating the instructions given in *Chapter 3: Introduction* and *Chapter 4: A first measurement* for the new measurement environment.

Tip

If you want to measure a single sample in air as well as in liquid, always perform the measurements in air first. This way, you will be able to judge sample height and perform sample approach more easily, as the manual coarse approach is more easily performed in air. It is also better for the cantilever to change from air to liquid than the reverse. A cantilever that has been exposed to liquid will — even when properly dried — never have the exact same physical properties as a cantilever that has never been exposed to liquid before. Therefore, only use cantilevers that have been exposed to liquid environments for new measurements in liquid.

- Improving measurement quality, as described in *Chapter 5: Improving measurement quality* (page 61).
- Performing a different type of measurement by choosing a different operating mode, as described in *Chapter 6: Operating modes* (page 66).
- Finishing measurements, turning off the instrument, and/or storing the instrument, as described in *Chapter 6: Finishing measurements* (page 69).

CHAPTER 5:

Improving measurement quality

5.1: Removing interfering signals

Interfering signals can be recognized because they have a fixed frequency, usually a multiple of the local mains frequency (50 or 60 Hz) throughout the image. Thus, they are manifested by straight lines that run throughout the entire image.

Possible interference sources are:

- *Mechanical vibrations* from machines or heavy transformers in direct vicinity (e.g. pumps).
- *Electrical interference* (in the electronics, or in electrical forces of the tip–sample interaction).
- *Infrared and other light sources* (light bulbs, sample illumination in an inverted microscope).

5.1.1: Mechanical vibrations

Measure the frequency of the vibrations to find out if the interference is due to mechanical vibrations. Such vibrations have a frequency that is (a multiple of) the rotation frequency of the source. This frequency is usually not a multiple of the local mains frequency, and may change slightly over time. Try the following to find out if the interfering signal is due to mechanical vibrations:

1. If possible, turn off all rotating machines (i.e. pumps) in the room.
2. Change the vibration isolation by putting the Scan Head directly on the table, instead of on the Sample stage.

To reduce the influence of these vibrations, either improve the isolation of these machines, or improve the isolation of the instrument by using an active vibration isolation table (e.g. the optional Nanosurf Isostage or halcyonics_i4.

5.1.2: Electrical interference

Electrical interference may be caused by interference in the electronics, or by electrostatic forces acting between the tip and the sample. Try the following in order to reduce the influence of electrical interference:

1. Connect the instrument to the mains power supply using sockets with line filters and surge protection.
2. Connect the sample, the sample support, the Sample Holder to the ground connector on the Scan Head using the ground cable (*Figure 1-2: Contents of the Tool set* (page 18), item 1).

❸ Remove interfering electromagnetic field sources, such cathode ray tube displays, loudspeakers, etc.

5.1.3: Infrared and other light sources

Infrared and other light sources can influence the cantilever deflection detection system. This problem is especially severe when measuring in the Static Force mode. Try the following in order to reduce the influence of infrared light sources:

❶ Turn off the light.

❷ Shield the instrument from external light sources.

❸ When using the instrument with an inverted microscope, use filters that filter out infrared light.

5.2: Adjusting the measurement plane

Ideally, the sample surface and the XY-plane of the scanner run parallel to each other. In most cases, however, the sample plane is tilted with respect to the XY-plane of the scanner. In this case, the sample cross section in the X* measurement direction has a certain slope. The Line graph chart in *Figure 5-1: Maladjusted slope* is an example.

This slope depends on the direction of the X* direction and therefore on the rotation of the measurement, as shown in *Figure 5-2: Sample and measurement orientation before slope adjustment*.

This slope is undesirable for several reasons:

- It makes it difficult to see small details on the sample surface, because the Average, Plane fit, or higher order filters cannot be used properly.
- The Z-Controller functions less accurately, because it continuously has to compensate for the sample slope.

Ideally, the XY-plane of the scanner has already been correctly aligned with the sample plane using the three leveling screws on the Scan Head. This alignment can, however, not easily be performed once the automatic approach has been done, as this would damage the tip. After approach, the measurement plane should therefore be adjusted electronically. This can be done automatically or manually. Both procedures are described below.

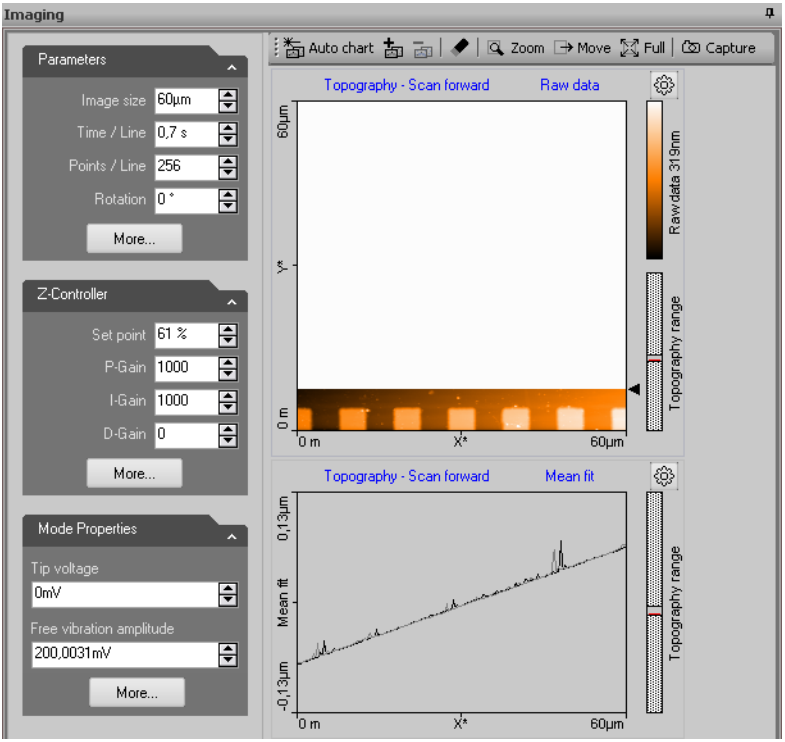


Figure 5-1: Maladjusted slope. Measurement with improperly set X*-slope.

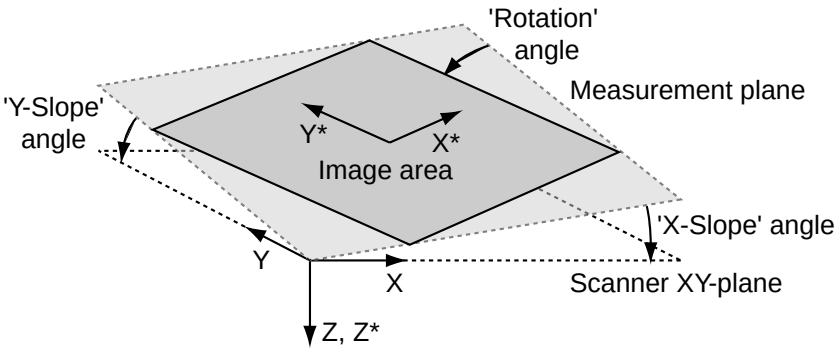


Figure 5-2: Sample and measurement orientation before slope adjustment

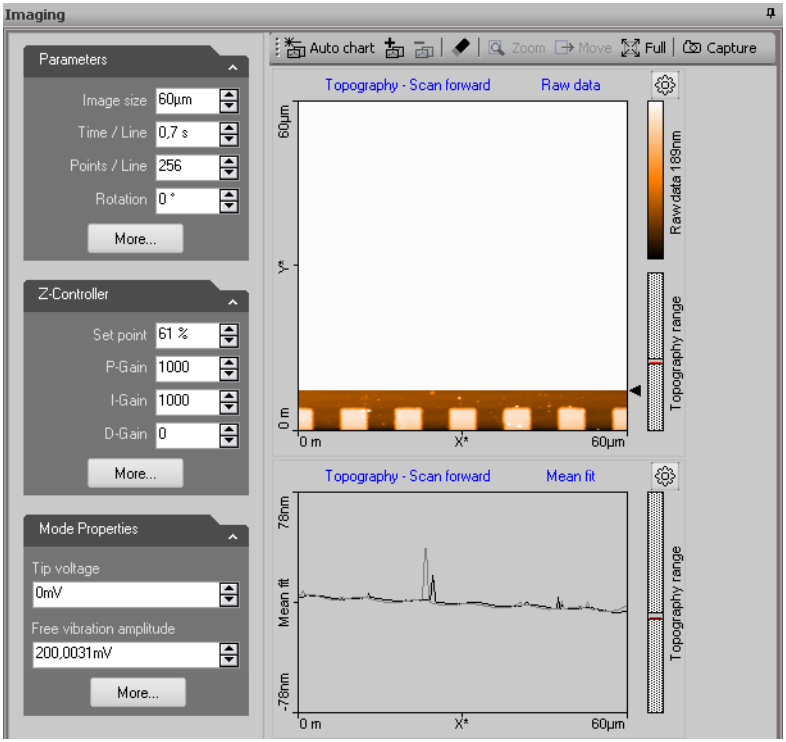
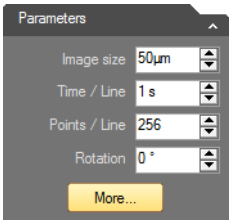


Figure 5-3: Adjusted slope. Measurement with properly set X*-slope.

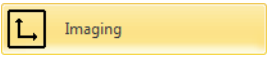
To automatically adjust the measurement plane once:

❶ In the Parameters section of the Imaging panel, click the “More” button:



The SPM Parameters dialog will now open (see *Section 7.9: SPM Parameters dialog* (page 86) for details). This dialog contains all possible parameters and settings that influence the behavior of your Nanosurf FlexAFM system.

❷ Make sure that "Imaging" is selected in the SPM Parameters dialog:



❸ Click the "Adjust slope" button:

The SPM Control Software will automatically perform a slope determination procedure similar to the manual procedure described below and will enter the slope angles into the X- and Y-Slope parameters.

IMPORTANT

If the sample surface contains large jumps or steps in height, the line fitting procedure used to determine the slope in X- and Y-direction may not deliver the best possible results. In such cases it is recommended to perform a manual slope adjustment as described below.

To automatically adjust the measurement plane before each measurement:

➔ Check the "Auto set" checkbox next to the "Adjust slope" button.

To manually adjust the measurement plane:

❶ Measure the slope for X in the Line graph using the angle tool (see *Measure Angle* (page 227)).

Use a single click instead of dragging the first line to create a horizontal line and measure the angle relative to the X*-Axis.

❷ Enter the result of the angle determination as X-Slope (see *Imaging options* (page 160)) and fine-tune its value until the X-axis of the scan line lies parallel to the X-axis of the sample.

❸ Set Rotation to 90° to scan along the Y-direction of the scanner.

❹ If the scan line in Y-direction is not horizontal, perform the same procedure as described for correction of the slope in X but now for Y.

❺ Reset "Rotation" to 0°.

The scanner scans in X-direction again.

5.3: Judging tip quality

When all prerequisites for measurement are optimal, the measurement quality mainly depends on the quality of the tip. A good tip quality is essential for high quality images and high resolution.

When the image quality deteriorates dramatically during a previously good measurement, the tip has most probably picked up some material from the sample. As a result, the image in the color map charts consist of uncorrelated lines or the image appear blurred (see *Chapter 5: Measurement containing tip artifacts*). In such cases:

- Follow the suggestions in *Section 17.3.3: Image quality suddenly deteriorates* (page 279). If these do not help, the cantilever should be replaced.

When all peaks in the image have the same, usually triangular shape, the sharp end of the tip may have broken off. The measured structure reflects the shape of the tip rather than that of the sample and is called a tip artefact. In such cases:

- Replace the cantilever.

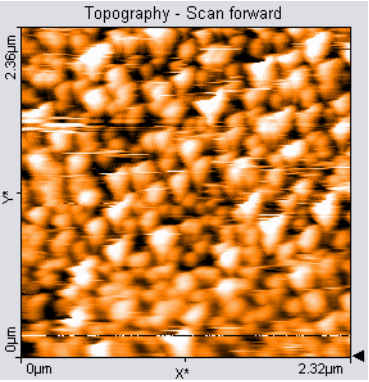


Figure 5-4: Measurement containing tip artifacts

CHAPTER 6:

Finishing measurements

6.1: Finishing scanning

Once you are done measuring:

1. In the Imaging group of the Acquisition tab, click the "Stop" button to stop measuring.
2. Open the positioning window.
3. If the FlexAFM Video Camera is installed, activate "Side view" in the Video panel (see *Section 9.2: Video panel* (page 128)).
   If the Video Camera is not installed, use the side view lens of the scan head to observe the sample instead.
4. Retract the cantilever to a safe distance from the sample by clicking and holding the "Retract" button in the Approach group of the Acquisition tab until the tip–sample distance is at least as large as shown in *Figure 6-1: Side view of the cantilever after retracting* or by clicking the "Home" button and waiting for the automatic full withdrawal process to finish.

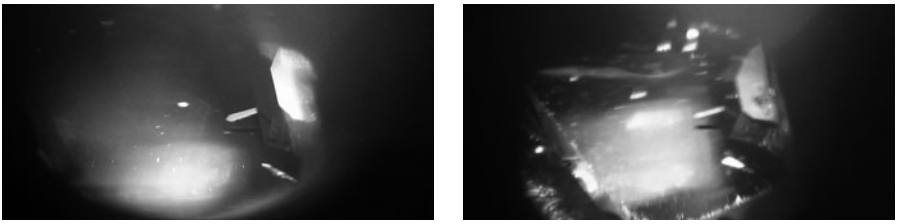


Figure 6-1: Side view of the cantilever after retracting. Minimal distance required for safe removal of the scan head and sample. (Left) in air, (Right) in liquid.

5. Turn down the sample platform of the FlexAFM sample stage.
6. Remove the sample or sample holder from the sample stage.
7. In case the measurement was performed in liquid, remove and clean sample holder, cantilever, and sample as described in *Section 3.3.2: Removing the Cantilever Holder* (page 35) and follow the instructions describing the removal of a used cantilever in *Section 3.3.3: Inserting the cantilever in the Cantilever Holder* (page 36).

6.2: Turning off the instrument

To turn off the instrument:

1. Finish as described in *Section 6.1: Finishing scanning*

2. Select the measurements that you want to keep in the History page of the Gallery panel and save them in a new folder (see *Save as* (page 220)).
3. Exit the SPM Control Software.
4. Turn off the power switch on the controller (see *Figure 1-4: The Easyscan 2 controller* (page 21) for its location).

6.3: Storing the instrument

If you are not using the instrument for an extended period of time, if you have to transport it, or if you send it in for repairs, put the instrument in the original packaging material.

1. Turn off the instrument as described in *Section 6.2: Turning off the instrument*, and remove all cables.
2. Leave the cantilever in the scan head, or replace it with an old one.
3. Put the Scan Head in its Scan Head Case
4. Pack all components in the original Nanosurf packaging material or instrument case.

IMPORTANT

Before transport, always put the Scan Head in the Scan Head case. Make sure the Scan Head is locked in tight. Put the instrument in the original Nanosurf packaging material.

PART B:

SOFTWARE REFERENCE

CHAPTER 7:

The user interface

7.1: General concept and layout

The SPM Control Software provides all functions to operate the microscope during imaging of surfaces and more advanced operating modes. It also provides data analysis functions for post-processing of measurement data.

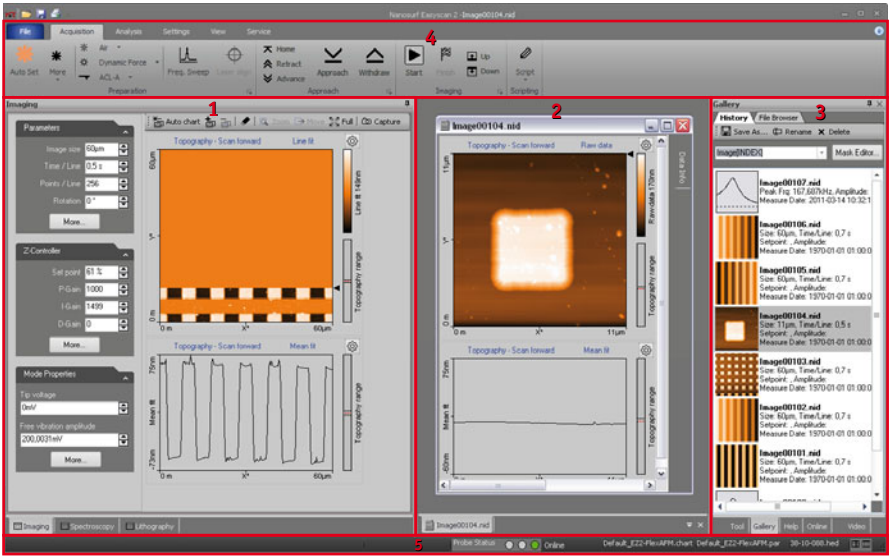


Figure 7-1: The main window in "Normal" workspace mode

The main SPM Control Software window (also referred to as workspace) consists of five major areas:

1. The Measurement pane on the left. This area contains the so-called *Operating windows*, which are used to acquire and display ongoing measurement data.
2. The *Document space* in the middle. This area is used for displaying and analyzing previously stored measurement documents.
3. The Info pane on the right. This area contains several stacked *Panels* and is used to group a diverse array of functionality and information.
4. The *Ribbon* at the top. This area is used to access all action functions.
5. The *Status bar* at the bottom. This area is used to display additional information.

7.2: The workspace

With the Nanosurf SPM Control Software, measurement of newly acquired data and analysis of already stored data (in multiple documents) can be performed in parallel, since these tasks are partly performed in different areas of the workspace. It may however require a high resolution monitor (or multiple monitors) to make this process efficient. To offer the same functionality on systems with a limited resolution, the user can switch between a "Normal" (*Figure 7-1: The main window in "Normal" workspace mode*) and a "Document" mode (*Figure 7-2: The main window in "Document" workspace mode*). See also *Section 7.8.1: Workspace group* (page 85).

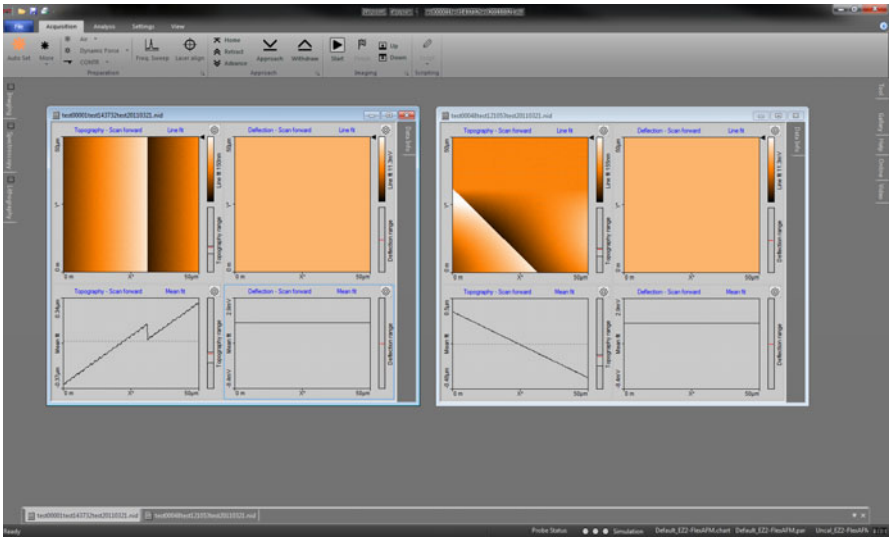


Figure 7-2: The main window in "Document" workspace mode

In "Normal" mode, the emphasis lies on the Measurement and Info panes. The inside border of the two panes can be dragged by the mouse to adjust their individual widths to your needs. Document space on the other hand is rather limited (see *Figure 7-1: The main window in "Normal" workspace mode*). This mode is most suited for measurements.

In "Document" mode, the Document space is maximized while the Measurement and Info panes are minimized to the left and right side of the main window, respectively (see *Figure 7-2: The main window in "Document" workspace mode*). The various window and panel titles are shown in tabs so that you can still open them when needed. A click or a mouse-over on one of these tabs will cause the respective window or panel to slide out automatically, so

that you can work on it. It will automatically minimize again when you are done. This mode is most suited for analyzing stored measurement data.

7.3: Operating windows

Operating windows are used to perform specific operations with the microscope. The Operating windows are grouped together in the Measurement pane and can be accessed by clicking the respective tab. The operations themselves are usually controlled using the action buttons of the Ribbon.

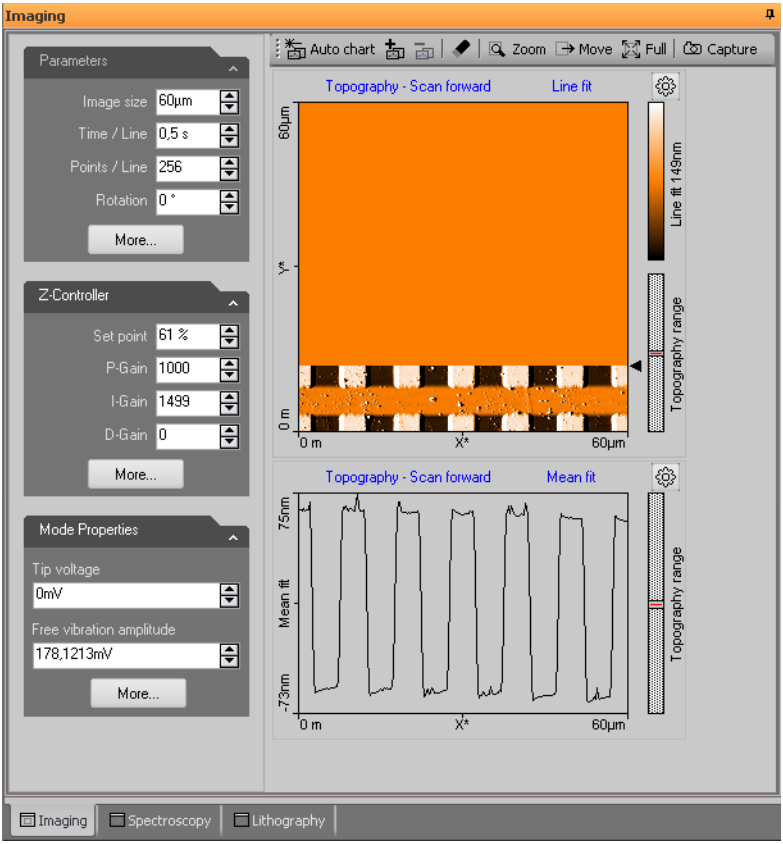


Figure 7-3: Elements of Operating windows. Shown here is the Imaging window, with the Parameter area (Imaging panel) on the left, the Chart area on the right, and the Chart bar on top. Clicking the tabs at the bottom of the Measurement pane switches between the Operating windows.

The Operating windows are:

- The Imaging window; used for generating images of a sample (for details see *Chapter 10: Imaging* (page 149)).
- Spectroscopy window; used for measuring various "A as a function of B" curves at certain sample locations, such as force–Distance curves or current-voltage curves (for details see *Chapter 11: Introduction* (page 164)).
- Lithography window; used for performing Lithography on the current scan area (for details see *Chapter 12: Lithography* (page 187)).

All Operating windows contain three distinct elements, which are described in *Figure 7-3: Elements of Operating windows* and in the next chapters:

1. The "*Parameter area*", where the main parameters influencing the current measurement are grouped into different sections.
2. The "*Chart area*", where one or more charts, showing different aspects/signals of the current measurement, are being displayed.
3. The "*Chart toolbar*", where several functions that directly influence the current measurement (or the way its displayed) are located.

7.3.1: Entering and changing parameter values

Parameter values can be found in the parameter sections of the Operating windows and in special dialogs (such as the *SPM Parameters dialog* (page 86)). Depending on your measurement (or optimization thereof), you may from time to time need to make changes there. To change a parameter or enter a value:

❶ Activate the parameter by clicking inside the (white) parameter edit box with the mouse:

❷ In case of a drop-down menu selection list, change the selection using the mouse or the up and down arrows on the keyboard. In case of a numerical value, use one of the following methods:

- Use the up and down arrow keys on the keyboard to increase or decrease its value. The new value is automatically used after one second.
- Click the arrow buttons next to the parameter value with the mouse pointer. Normally, the parameter value is changed by a small amount (usually in the range of 1–10%). Some edit boxes are doubling or dividing the parameter value by two (e.g. the "points/line" parameter). The new value is automatically used after one second.
- Enter the new value using the keyboard. The entered value is applied upon pressing the "Enter" or "Return" key, or by activating another input. The entered value is discarded upon pressing the "Esc" key. The unit prefix can be changed by typing one

of the following keyboard keys:

f = femto	space bar	=	no prefix
p = pico	k	=	kilo
n = nano	M (shift-m)	=	mega
u = micro	G (shift-g)	=	giga
m = milli	T (shift-t)	=	tera

Examples: if the basic unit is Volts, type “m” to change to millivolts, type the space bar for volts, type “u” for microvolts.

Sometimes the program will change an entered value to a slightly different value. This happens when the desired value is outside the digitization range of the Easyscan 2 controller, for example due to resolution or timing limits. In such cases, the desired value is automatically changed to the nearest possible value.

7.4: Document space

In the document space, stored measurements can be displayed for evaluation and analysis. Each measurement is contained within its own document window. These windows can be arranged in document space to your liking.

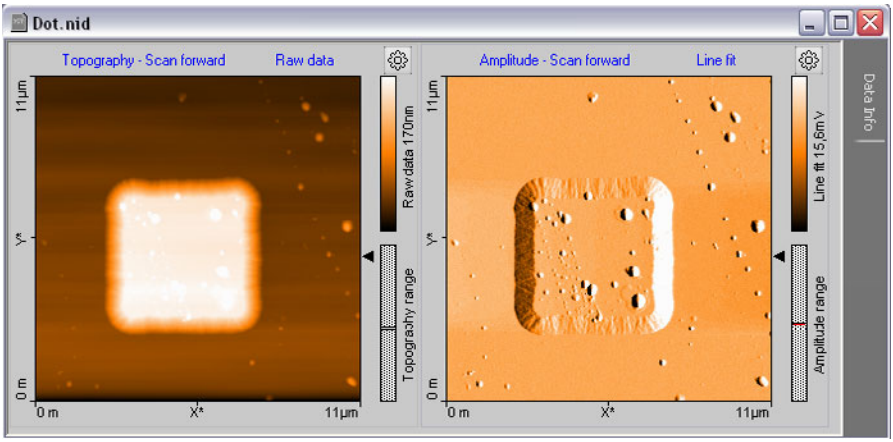


Figure 7-4: Example of a measurement document window

By default, all measurements are temporarily stored (automatically) during imaging and spectroscopy. They can be opened at all times from the Gallery panel (see *Section 13.4: Gallery panel* (page 219)), but should be moved to a new folder for permanent storage as soon as you have finished measuring (see *Save as* (page 220)).

Everything related to documents is described in more detail in *Chapter 13: Working with documents* (page 207).

7.5: Panels

In the panels of the Info pane, the control software provides additional information that can be useful to the user. These panels are normally docked to the Info pane and are stacked to save space. The panels have several features, however, that allow you to arrange them in a way that is most efficient for your application (see *Figure 7-5: Arranging panels*).

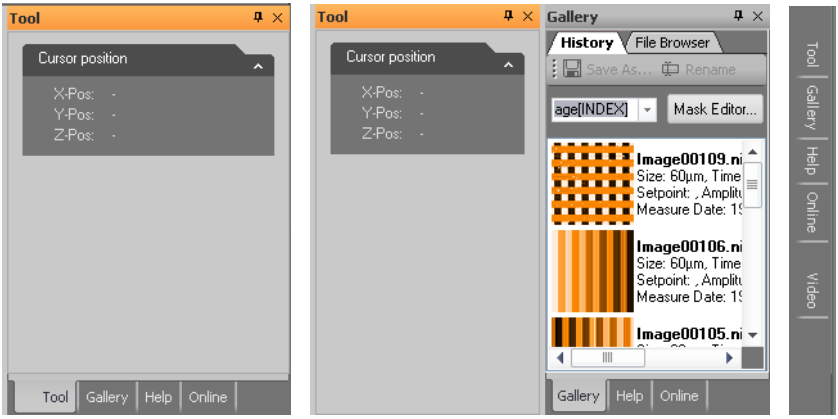


Figure 7-5: Arranging panels. (Left) Stacked panels. (Center) Separated panel that is docked to a stack. (Right) Panels that are minimized in "Document" mode.

To separate a panel and dock it individually to the side of/below another panel that is already docked to this window, drag its title bar to the desired position using the mouse cursor.

To add a control panel to a stack, drag either its title bar or its label to either the title bar or labels of the stack. To remove a panel from a stack, drag its label away from the stack.

When panels are stacked, their title labels are displayed on the bottom of the Info pane. To move a control panel to the top of the stack, click its tab.

With the "pin" button ( ) in the tile bar of the individual panel or the Info pane, the auto hide feature is controlled. If "unpinned", the panel or the Info pane minimizes to the right border of the main window and only the panel titles are visible (similar to the "Documents" workspace mode, but now only for the panel/Info pane and not for the Measurement area). A mouse hover over (or click on) a title tab will slide this panel into view.

It is possible to scroll the content of a control panel up and down, when it is too small to display all the parameters it contains. To do this, move the mouse cursor over an area where it changes to a four pointed arrow. Then, drag the content up and down with the mouse.

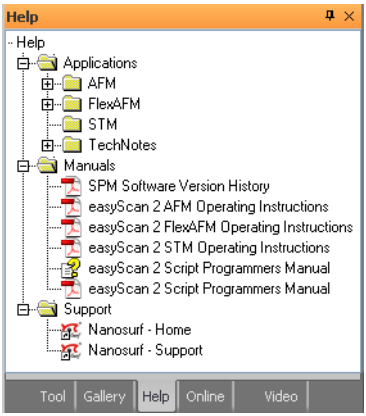
Tool

The Tool panel contains the results of the various analysis tools available to you during and after measurement, displays the current mouse position during selections, and displays the size of those selections (e.g. during zooming). The Tool panel is described in more detail in *Section 13.6: Tool panel* (page 236).

Gallery

The Gallery panel displays a list of stored measurements for quick opening (viewing and analysis). A File Browser is also integrated for general file management tasks. The Gallery panel is described in more detail in *Section 13.4: Gallery panel* (page 219).

Help



The Help Panel provides quick access to PDF versions of the user manuals belonging to your system, to relevant application notes and technical notes, and to online sources of information (direct links to the Nanosurf website).

Online

The Online Panel provides you with an overview of the current scan range within the maximum range the scanner is capable of (Scan Position section), a “Master image” that can be used as a reference for multiple zoomed scans on different points of interest (Master Image section) and a simple illumination control (Illumination section). The Online panel is described in more detail in *Section 9.3: Online panel* (page 135).

Video

The Video panel with its top and side view of cantilever and sample is particularly useful during sample positioning and approach (see also *Section 4.4: Approaching the sample* (page 48)). The elements and usage of the Video panel is described in *Section 9.2: Video panel* (page 128).

Stage

The Stage panel can be used to control the automated translation stages (ATS A100 or ATS C301), but is only available when the Translation Stage software is installed. The Stage panel is explained in *Section 9.4: Stage panel* (page 137).

7.6: Ribbon

The Ribbon provides access to all major actions and commands by grouping them according to their usage.

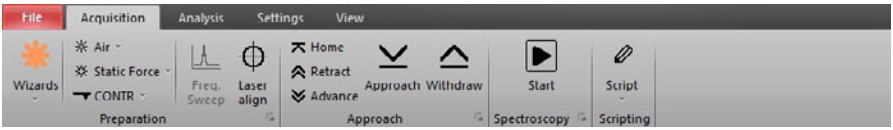


Figure 7-6: The Ribbon.

The File menu

The File menu contains commands to open, save and print measurements. Other files such as those containing parameter settings or chart properties can be loaded or saved here as well. The file menu also provides data export functions. General program settings are configured through the Options dialog, which is opened by clicking the "Options" button of the File menu. The File menu is described in *Section 14.1: File menu* (page 242).

The Acquisition tab

Guides you through the measurement process. There are groups of buttons for measurement preparation, sample approach and the measurement itself. The Preparation and Approach groups are constant and described in *Chapter 9: Positioning* (page 127) and *Chapter 9: Positioning* (page 127), respectively. The content of the other groups varies with the Measurement window that is selected (*Imaging*, *Spectroscopy* and *Lithography*) and is therefore described in the respective chapters.

The Analysis tab

Contains measurement data functions for extracting information from your measurements (e.g. "step height" or "roughness"). It also provides functions to permanently modify your image data (e.g. "backplane removal" or "noise filtering". All of these functions are described in *Section 13.5: Analysis tab* (page 224).

The Settings tab

Contains functions to configure the microscope controller hardware and calibrating the scan head. It is described in *Section 14.2: Settings tab* (page 249)

The View tab

Provides access to the workspace modes "Normal" and "Documents" (see *Section 7.4: Document space* and *Section 7.8.1: Workspace group*), the Panels of the Info pane, and Document window arrangement options. Since it has a great impact on the overall look of the user interface of the SPM Control Software, it is described below (see *Section 7.8: View tab*).

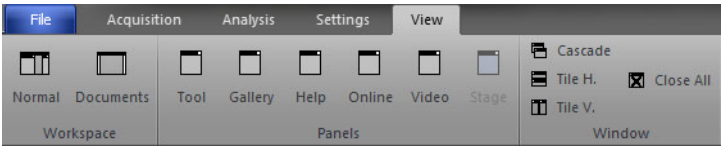
7.7: Status bar

Figure 7-7: The Status bar. Numbers in this figure correspond to those in the list below.

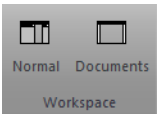
The status bar displays relevant microscope information and the loaded settings (see *Figure 7-7: The Status bar*). It contains the following elements:

1. Help text information about the current menu button or latest error messages
2. Status signal of the Z-feedback controller (red: in upper limit positions; orange: in lower limit position; green: tip in normal feedback contact with sample).
3. Software status: "Online" or "Simulation" (depends on the presence or absence of a scan head, or on user choice).
4. Currently loaded file (".chart") used for chart settings.
5. Currently loaded file (".par") used for parameter settings.
6. Currently loaded scan head calibration file (".hed").
7. Buttons to access the Workspace "Normal" and "Document" view.

7.8: View tab



7.8.1: Workspace group



The workspace group in the view tab gives you the ability to switch between the two workspace modes “Normal” and “Documents”. To switch, click on either of the buttons, or on the corresponding smaller buttons ( ) on the right-hand side of the status bar (see also *Section 7.7: Status bar*). With these you don't even need to switch to the view tab while measuring.

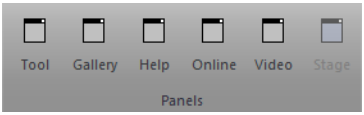
Normal

The optimal workspace choice during measurements.

Documents

The best choice for viewing or analysis of stored documents (see *Chapter 13: Working with documents* (page 207)).

7.8.2: Panels group

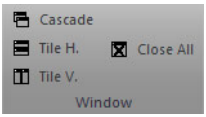


The buttons of the Panels group have the same function as the tabs at the bottom of the Info pane (i.e., to bring the respective panel to the top of Info pane). If the panel was undocked from the Info pane (see *Section 7.5: Panels*) and subsequently closed (i.e., no longer visible as panel or tab), it will re-appear by pressing its button in the Panels group.

IMPORTANT

The “Video” and “Stage” buttons are only available when the appropriate hardware is present.

7.8.3: Window group



The window group provides you with tools to arrange open measurement documents in different ways or quickly close them all.

Cascade

Open document windows are stacked on top of each other and slightly offset with respect to each other so that individual windows can be easily accessed. Width and position of the windows is optimized by the control software.

Tile H.

Tiles the open document windows horizontally, so that individual measurements can be easily compared. Width of the document windows is maximized. Height is evenly distributed over the available document space.

Tile V.

Tiles the open document windows vertically, so that individual measurements can be easily compared. Height of the document windows is maximized. Width is evenly distributed over the available document space.

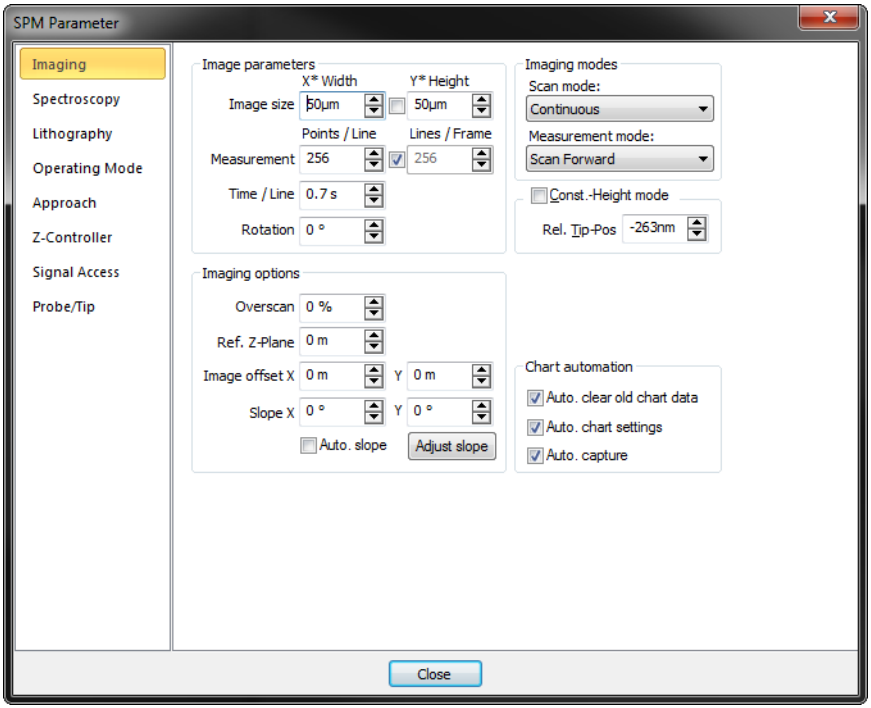
Close all

Closes all open document windows. If unsaved data exists, you will be asked to save it.

7.9: SPM Parameters dialog

While not directly visible upon starting the Nanosurf SPM Control software, the SPM Parameters dialog is essential for controlling many advanced parameters during measuring. The dialog is opened by clicking the “More” button that can be found in many of the parameter sections of the measurement panels. It can stay open during all

operations to provide the advanced user with a permanent and detailed control over all measurement parameters.



The SPM Parameters dialog is divided into several (sub-)pages:

- Imaging (see *Section 10.5.1: Imaging page* (page 159))
- Spectroscopy (see *Section 11.6.1: Spectroscopy page* (page 180))
- Lithography (see *Section 12.7.1: Lithography page* (page 205))
- Operating mode (see *Section 8.11.1: Operating Mode page* (page 113))
- Approach (see *Section 9.6.1: Approach page* (page 141))
- Z-Controller (see *Section 8.11.2: Z-Controller page* (page 115))
- Signal Access (see *Section 14.8.1: Signal Access page* (page 259))
- Probe/Tip (see *Section 14.8.2: Probe/Tip page* (page 262)

For a detailed description of all available functions and settings, see the respective manual pages.

CHAPTER 8:

Operating modes

8.1: Introduction

This chapter instructs you on how to use the *Static Force mode*, *Dynamic Force mode*, *Phase Contrast mode*, *Force Modulation mode*, *Spreading Resistance mode* and *Lateral Force mode*. If you are unfamiliar with Atomic Force Microscopy techniques, it is recommended to first read *Chapter 18: AFM theory* (page 283).

The amount of available modes depends on the scan head and the available modules built into the Easyscan 2 controller. The modules required to be able to use a certain operating mode are listed in *Table 8-1: Operating modes and required modules*. If additional hardware is required, it will be discussed in the respective section explaining the measurement mode.

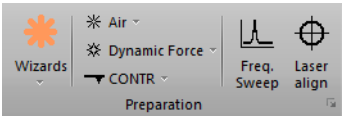
Operating mode	Required modules
Static Force	AFM Basic
Dynamic Force	AFM Basic, AFM Dynamic
Phase Contrast	AFM Basic, AFM Dynamic, AFM Mode Extension
Force Modulation	AFM Basic, AFM Dynamic, AFM Mode Extension
Spreading Resistance	AFM Basic, AFM Mode Extension
Lateral Force	AFM Basic, AFM Mode Extension
Kelvin Probe Force	AFM Basic, AFM Dynamic, Signal Module A
Scanning Thermal	AFM Basic, Signal Module A

Table 8-1: Operating modes and required modules

Operating modes can be selected in the Preparations group of the Ribbon's Acquisition tab. Appropriate parameters can either be set manually or via one of the Preparation wizards. These possibilities are explained in *Section 8.2.1: Preparation group*.

8.2: Acquisition tab

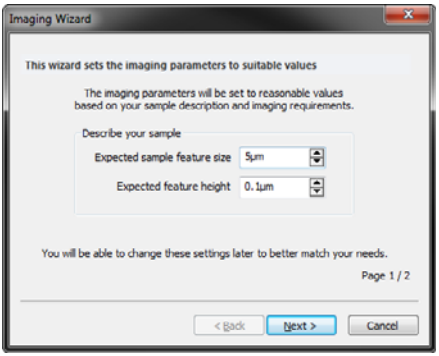
8.2.1: Preparation group

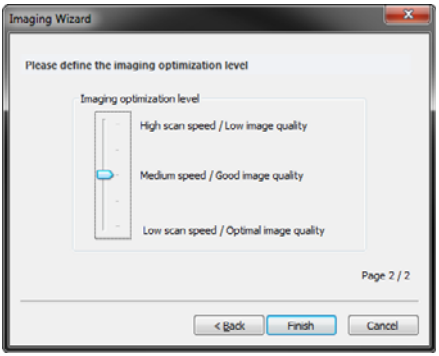


Wizards

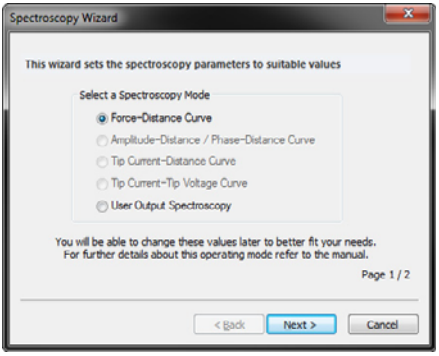
The "Wizards" button opens up various Parameter preparation wizards (select the appropriate one from the drop-down menu). Available options are:

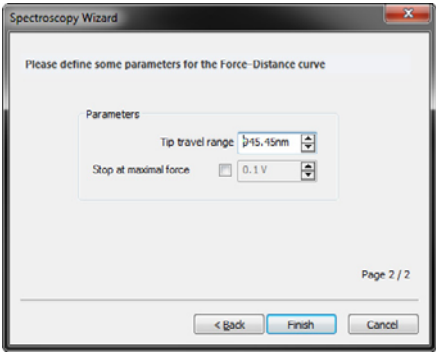
– **Imaging...**
Prepares imaging parameters based on the currently selected operating mode, your sample description, and your imaging requirements (as provided in the Imaging Wizard dialog screens):



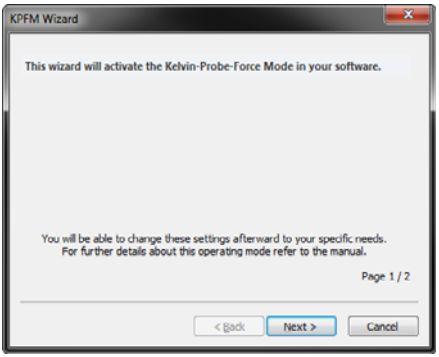


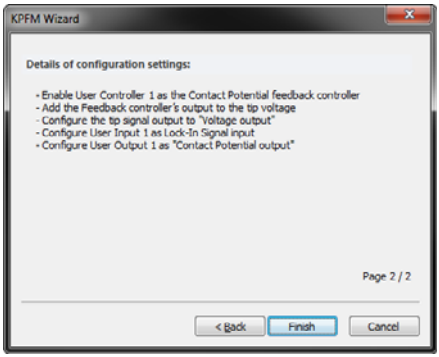
– **Spectroscopy...**
Quickly set parameters for spectroscopy measurements on a sample (see *Section 11.2: Spectroscopy Wizard* (page 166) for further details):





– **KPFM ...**
  Automatically set parameters for the KPFM operating mode (see *Section 8.9: Kelvin Probe Force Microscopy* for further settings and hardware configuration):





Environment
This drop-down box allows the selection of either “Air” or “Liquid” as measurement environment. Depending on the used scan head, certain options may or may not be available.

Operating Mode
This drop-down box allows the selection of the Operating mode used for measuring (see *Section 8.4: Dynamic Force mode* and onward). Depending on the installed controller modules and the mounted scan head, certain options may or may not be available.

Cantilever Selector
This drop-down box allows the selection of the mounted cantilever in case of AFM scan heads. For more details see *Section 3.3.1: Selecting a cantilever* (page 34). Depending on your scan head type, certain options may or may not be available. The entry “Cantilever Browser…” opens the Cantilever Browser dialog, which allows you to edit existing or define new cantilever types (see *Section 8.12: Cantilever Browser dialog* (page 117))

Freq. Sweep
This button opens the Vibration Frequency Search dialog. In this dialog, amplitude versus frequency plots can be measured and the operating frequency for dynamic modes can be set manually. In “Air” environment, setting of the vibration frequency is normally performed fully automatically, without user intervention. In “Liquid” environment, the Vibration Frequency Search dialog opens after the control software determined a suitable vibration frequency. You need to fine adjust and confirm the selected resonance frequency prior to approach. For more details about this dialog see *Section 8.12: Cantilever Browser dialog* (page 117).

Laser Align
This button opens the Laser Align dialog. In this dialog, laser power and the current position of the laser beam on the detector are monitored. It is used to check for good detector and laser alignment. With FlexAFM scan heads it guides the user to manually adjust these positions if required or desired (see FlexAFM Laser and detector alignment).

Launcher icon
More advanced settings are available through the "Dialog Launcher" icon (at the bottom right corner of the Preparation group), which opens up the SPM Parameters dialog on the Operating Mode page (see *Section 8.11.1: Operating Mode page* (page 113)).

8.3: Static Force mode

In the Static Force mode, the "static" deflection of the cantilever is used as the error signal for the Z-Controller. The Setpoint in Newton is calculated by multiplying the deflection with the spring constant of the selected cantilever. In order to minimize tip/sample wear, the force Setpoint should be made as small as possible. In some cases, even a negative Setpoint (i.e. an adhesive force) may work, but when the tip momentarily loses contact with the sample due to some disturbance, the Z-Controller will always fully retract the cantilever from the sample. Moreover, working in this range may cause image artifacts due to instabilities in the tip–sample contact.

Both the Force Modulation mode and the Spreading Resistance mode are an extension of the Static Force mode.

The procedure for a first Static Force mode measurement is almost identical to the procedure described for the Dynamic Force mode in *Chapter 4: A first measurement* (page 45). In contrast to the description given there, however, do the following:

1. Select a cantilever suitable for static force mode (e.g. CONTR).
2. Install the cantilever as described in *Section 3.3: Installing the cantilever* (page 33).
3. Select this cantilever type in the Preparation group of the Acquisition tab.
4. Select the Static Force mode in this group as well.
5. Set the force Setpoint in the Z-Controller section of the Imaging window.

For a more detailed description of the parameters that can be set, refer to *Section 8.11.1: Operating Mode page* (page 113).

8.4: Dynamic Force mode

In the Dynamic Force mode, changes in the dynamic behavior of the cantilever are detected by measuring changes in its vibration amplitude when it is excited with a

sinusoidal signal with a frequency close to the free resonance frequency of the cantilever. When the cantilever tip comes close to the sample surface, this vibration amplitude will generally go down. Thus the Setpoint is the percentage of the vibration amplitude that remains when the cantilever is close to the sample surface compared to the vibration amplitude when the cantilever is far away from the surface. A small percentage means a big reduction, and a large percentage means a small reduction. To minimize tip/sample wear, the Setpoint should be set as large as possible. However, when the Set-point becomes too large, the Z-Controller may not be able to optimally follow the sample surface, and artifacts may occur due to instabilities in the cantilever vibration.

The procedure for a first Dynamic Force mode measurement is described for the Dynamic Force mode in *Chapter 4: A first measurement* (page 45). For more information on how the vibration amplitude and frequency are set, refer to *Section 8.11.1: Operating Mode page* and *Section 8.13: Vibration Frequency Search dialog*.

8.5: Phase Contrast mode

The Phase Contrast mode is an extension of the Dynamic Force mode. Therefore, the same cantilevers can be used as for Dynamic force mode. In addition to the vibration amplitude, the phase shift between the cantilever vibration and a reference signal is measured. This phase shift changes when the resonance characteristic of the cantilever changes due to changes in the tip–sample interaction. Thus, the Phase contrast mode can be used to produce material contrast when there is a significant difference in the tip sample interaction of these materials. This section gives a brief description of how to operate the FlexAFM in phase contrast mode. For a more detailed description of the parameters that can be, refer to section *Section 8.11.1: Operating Mode page* (page 113).

The phase contrast mode can also be used to do Magnetic and Electrostatic Force Microscopy. For more information on how to do Magnetic Force Microscopy, refer to technical note *TN00031 Magnetic Force Microscopy*, which can be downloaded from the support section of the Nanosurf web site at *www.nanosurf.com*.

Phase measurement

In Phase contrast mode, the phase of the measured cantilever vibration is compared to the phase of a reference sine wave. The phase comparison is performed by multiplying the measured vibration signal with the reference. The measured phase, $\phi_{measured}$, is the output of this multiplication, and is related to the actual phase shift between the measured vibration and the excitation sine wave, ϕ_{actual}, according to the following equation:

$$\phi_{measured} = 90° \sin(\phi_{actual} - \phi_{reference}),$$

where $\phi_{reference}$ is a reference phase that can be set by the user. This has two important consequences:

1. The measured phase shift lies between –90° and +90°; phase shifts outside this range are folded back into the –90° to +90° range. The measurement does not distinguish between phase ϕ and phase $\phi + 180°$.
2. The phase shift measurement becomes less sensitive when the phase approaches +90° and –90°.

Note that the phase of the cantilever vibration changes by 180° symmetrically around its resonance frequency. This phase shift only fits into the –90° to +90° range when the reference phase is set in such a way that it is zero at the resonance frequency. However, the operating frequency is generally set to be different from the resonance frequency. In such cases, the reference phase is automatically set so that the phase shift is zero at the operating frequency. Thus, part of the frequency spectrum of the phase shift will be folded back into the –90° to +90° range (*Figure 8-8: Phase shift folded back*).

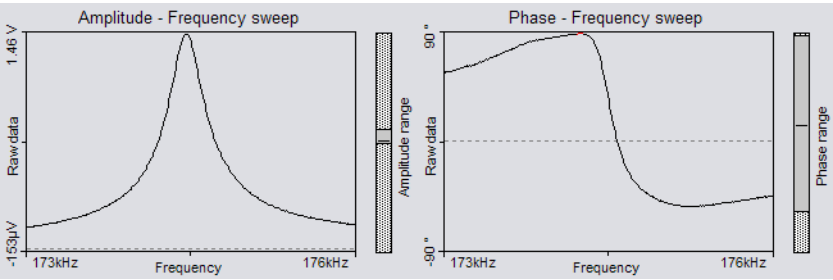


Figure 8-8: Phase shift folded back. Frequency spectrum with phase shift folded back over the +90° limit.

Operating the FlexAFM in Phase Contrast mode

To operate the FlexAFM in Phase Contrast mode:

➔ Select the Phase Contrast mode in the Preparation group of the Acquisition tab.

A new Color map and line chart for the phase data will automatically be added to the chart area. If necessary, you can increase the size of the measurement pane to make room for the new charts.

After approach, the reference phase is usually set automatically in such a way that the average phase shift lies in the center of the measurement range. To re-adjust the phase shift:

➔ Click the "Freq. Sweep" button in the Preparation group of the Acquisition tab.

If you do not want the reference phase to be set automatically:

❶ Open the SPM Parameters dialog by clicking the "More" button in the Mode Properties section of the Imaging window.

❷ Uncheck the reference phase “Auto set” checkbox.

❸ Enter the reference phase manually using the “Reference phase” input box.

8.6: Force Modulation mode

The Force Modulation mode is an extension of the Static force mode. The static force acting on the cantilever is still used to produce a topography image of the sample. Simultaneously, the cantilever is excited and the resulting vibration amplitude measured. The vibration amplitude depends on the drive amplitude, the stiffness of the cantilever and, most importantly, the stiffness of the tip–sample contact. Thus, the force modulation mode can be used to produce material contrast when there is a significant difference in the stiffness of the tip–sample contact of these materials. This section gives a brief description of how to operate the FlexAFM in force modulation mode. For a more detailed description of the parameters that you can set, refer to *Section 8.11.1: Operating Mode page* (page 113).

To operate the FlexAFM in the Force Modulation mode:

❶ Select a cantilever that has a spring constant that is suitable for the sample stiffness that you expect.

Good results were obtained with LFMR-type cantilevers. The FMR type cantilever, which is explicitly sold for Force Modulation mode measurements, cannot be used due to its insufficient width.

❷ Install the cantilever as described in *Section 3.3: Installing the cantilever* (page 33).

❸ In the Preparation group of the Acquisition tab, select the Force Modulation operating mode.

❹ In the Z-Controller section of the Imaging window, verify the force Setpoint.

❺ In the Preparation group of the Acquisition tab, click the “Freq. seep” button.

❻ Click the “Auto frequency set” button to measure the frequency characteristic of the cantilever.

❼ Make a note of the cantilever resonance frequency from the sweep chart and set “Vibration frequency” to this value.

❽ Set “Vibration amplitude” to the desired modulation amplitude.

❾ Increase the vibration amplitude if no proper Force Modulation signal can be measured.

8.7: Spreading Resistance mode

The Spreading Resistance mode is an extension of the static force mode. The static force acting on the cantilever is used to produce a topography image of the sample. Simultaneously, changes in the spreading resistance from the cantilever tip to a ground contact on a sample can be imaged by measuring changes in tip current while a fixed voltage is applied to the tip. This section gives a brief description of how to operate the FlexAFM in Spreading Resistance mode. For a more detailed description of the parameters that you can set, refer to *Section 8.11.1: Operating Mode page* (page 113).

To operate the FlexAFM in the Spreading Resistance mode:

1. Electrically connect the sample to the Ground connector on the FlexAFM Scan Head (*Figure 1-3: Parts of the Scan Head* (page 20)) via a 100 kOhm resistor in order to prevent damage to the tip due to an excessive current.

   For best results, the sample should be electrically isolated except for the connection mentioned above.

2. Select a suitable cantilever:
   - CDT-NCLR should be used for samples where a high force is needed to penetrate a surface oxide layer.
   - CONT-PtIr cantilevers can be used on delicate samples. The applied voltage should be small, because high currents may cause the conducting layer on the tip to evaporate. Also, applied forces should be very small to prevent damage to the conducting layer.
   - NCL-PtIr cantilevers could be used in combination with non-contact topography measurements, but damage to the tip is likely.

IMPORTANT

- Standard CONTR cantilevers cannot be used due to the surface oxide on the tip, and the semiconducting contact between the tip and the sample.
- EFM cantilevers cannot be used for static force mode measurements, due to their insufficient width.

3. Install the cantilever as described in *Section 3.3: Installing the cantilever* (page 33).
4. In the Preparation group of the Acquisition tab, select the Spreading Resistance operating mode.
5. In the Z-Controller section of the Imaging window, verify the Setpoint.
6. In the Mode Properties section, set the Tip voltage to your requirements.

8.8: Lateral Force mode

Lateral Force mode measures lateral deflections (twisting) of the cantilever that arise from forces working on the cantilever parallel to the plane of the sample surface when scanning in Static Force mode. Lateral Force mode is useful for imaging variations in surface friction that can arise from inhomogeneity in surface material, and also for obtaining edge-enhanced images of any surface. Recording lateral deflections of the cantilever in addition to vertical deflections requires a 4-quadrant split photodiode or other type of 2-dimensional position sensitive detector.

A lateral force during scanning usually arises from either or both of the following two sources:

- Changes in surface friction: in this case, the tip may experience greater friction as it traverses some areas compared to others, causing the cantilever to twist more.
- Rapid changes in surface height: in this case, the cantilever may twist when it encounters a steep slope and the Z-feedback controller cannot correct for it fast enough.

To be able to separate one effect from the other, Lateral Force and topography data should always be collected simultaneously.

To operate the FlexAFM in the Lateral Force mode:

1. Select a cantilever suited for Lateral Force measurements.
   Good results were obtained with LFMR-type cantilevers.
2. Install the cantilever as described in *Section 3.3: Installing the cantilever* (page 33).
3. In the Preparation group of the Acquisition tab, select the Lateral Force operating mode.
4. If necessary, change the force Setpoint in the Z-Controller section of the Imaging window.

8.9: Kelvin Probe Force Microscopy

8.9.1: Introduction

Kelvin Probe Force Microscopy (KPFM) is an extension of AFM. The technique was first published in 1991 by Nonnenmacher and co-workers. Using KPFM, images can be recorded that contain information on the local work function or local contact potential difference between tip and sample.

8.9.2: Operating principle

KPFM uses the mechanical response of a cantilever to a voltage difference between tip and sample. The voltage difference consists of two parts: an alternating current (AC) voltage and a direct current (DC) voltage. The mechanical response to the AC voltage depends on the DC voltage and becomes zero when there is no contact potential difference between the tip and surface. During normal dynamic mode imaging, a second feedback loop adjusts the DC voltage to minimize the mechanical response to the AC voltage. The DC voltage that needs to be applied to achieve this situation is therefore a measure for the local contact potential of the surface.

The AC voltage is applied at a frequency different from the normal cantilever oscillation, which normally is at or close to the cantilever resonance frequency. By going to a frequency well below its resonance, the mechanical response of the cantilever will be in phase with the AC voltage. To increase the mechanical response of the cantilever, the AC voltage can also be applied at the next higher resonance frequency of the cantilever.

On Nanosurf AFMs, the KPFM signal and topography data can be recorded in a single scan. Although all current Nanosurf AFMs (Nanite systems with SPM S200 controller, as well as all Easyscan 2 AFM systems with AFM Dynamic Module) are in principle capable of performing KPFM, the FlexAFM has demonstrated best KPFM performance and is therefore the instrument of choice for this type of measurement.

8.9.3: System requirements

Overview

System:	Nanite	Easyscan 2
Controller	SPM S200	All Easyscan 2 controllers equipped with AFM Dynamic Module
Scan Head	All beam deflection (B-type) scan heads	AFM or FlexAFM
Signal Module A	Version 6 or newer	Version 6 or newer
Lock-in amplifier	Yes	Yes
Cantilevers	Conductive with alignment structures and suited for dynamic operation	Conductive with alignment structures and suited for dynamic operation

Table 8-2: Components and modules required to perform KPFM.

For KPFM experiments, beam deflection-type scan heads equipped with conductive cantilevers (for example commercially available EFM cantilevers) are required.

An excitation source is required to provide the AC signal. In addition, a signal detection source that can filter out mechanical movements of the cantilever at the frequency of the modulation needs to be used. Both excitation and frequency-selective detection can be accomplished using a Lock-in amplifier.

Hardware setup

The KPFM setup for Nanosurf AFMs will schematically look as depicted in *Figure 8-9: KPFM connection schematics*. The User Controller 1 of the SPM Control Software is used as PID

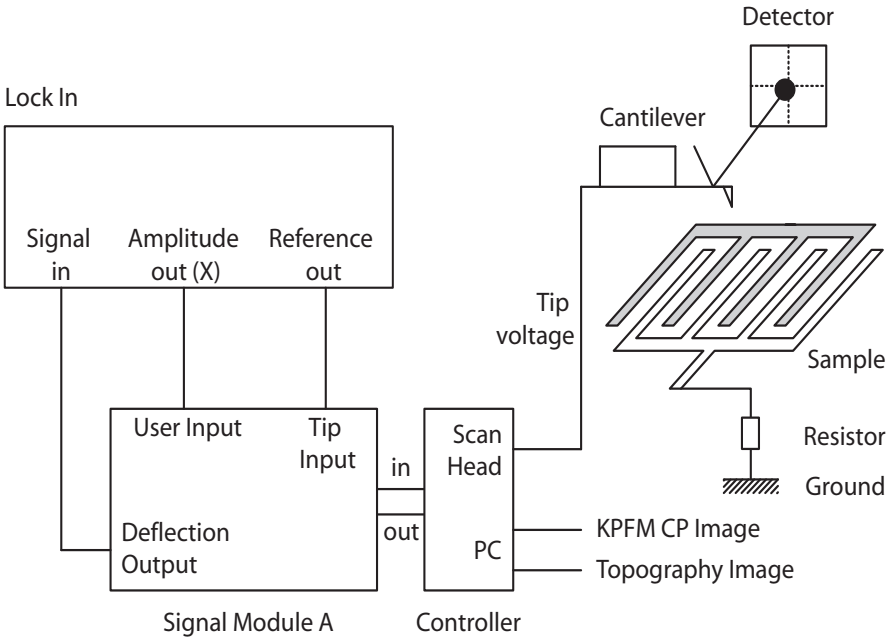


Figure 8-9: KPFM connection schematics.

controller to regulate the applied DC voltage. Signal Module A is used for communication between the AFM and the Lock-in amplifier.

Three cables are required to connect the Signal Module A (featuring BNC connectors) to the Lock-in amplifier (depending on the model used, most likely also equipped with BNC connectors).

The reference output of the Lock-in amplifier is used to generate the AC voltage. This wire is connected to the cantilever via the "Tip Voltage" connector on the input side of Signal Module A.

The mechanical response of the cantilever is measured on the cantilever deflection channel by connecting "Current or Deflection" on the output side of Signal Module A to the "Signal in" of the Lock-in amplifier.

The X-channel output of the Lock-in is connected to the User 1 connector on the input side of Signal Module A (see the last sentence of the *Lock-in settings* section for an explanation as to why the X-channel is used).

If the alternating voltage is applied to the cantilever, the sample has to be grounded. Nanosurf can supply thin cables that can be inserted into the ground connector of the scan head. A resistor between sample and ground can help prevent short circuits occurring between tip and sample.

Alternative setup

Instead of applying the alternating voltage to the cantilever tip, it can also be applied to the sample support. In this case the ground connection has to be removed from the sample support and needs to be replaced by a direct connection to the "Reference out" connector of the Lock-in amplifier, which in turn should no longer be connected to "Tip Voltage" of Signal Module A.

8.9.4: Procedures

Lock-in settings

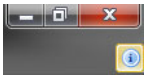
There are several approaches for selecting the reference frequency of the Lock-in:

- **AC frequency below the resonance frequency of the cantilever**
  At these low frequencies, the cantilever is in a forced oscillation and the mechanical response of the cantilever and the excitation are almost at the same phase or close to the opposite phase (depending on whether the forces between tip and surface are attractive or repulsive).
- **AC frequency at a higher oscillation mode of the cantilever**
  In these situations, the cantilever oscillation is self-amplifying.

Note that in both cases, the frequency that can be applied to the tip is limited by a filter present in the "Tip Voltage" channel of Signal Module A. The maximum frequency that can be applied depends on the version number of your Signal Module A.

To identify the installed Signal Module A version number:

1. In the upper right corner of the control software window, just beneath the Window's Close button, click the "About" button:



2. Locate the "Signal Module A" entry in the list of installed modules.

   In case of Signal Module A version 6 or newer:

   - Set the excitation frequency applied to the cantilever tip to 15 kHz.

   In case of lower Signal Module A version numbers:

   - Either apply a 1 kHz excitation frequency to the tip, or apply 15 kHz to the sample instead of the tip (see *Alternative setup* (page 101)).

In the AFM controller, the amplitude response of the cantilever to the applied AC voltage is kept minimal by variation of a DC voltage. The relation between the surface potential and the DC voltage required to obtain this minimal mechanical response is best understood, and this situation is therefore aimed at. Since the amplitude signal is always positive (independent of the sign of the force), it cannot be used to obtain opposite feedback responses for the attractive or repulsive forces. Therefore:

- Set the output of the Lock-in amplifier to "XY" instead of to "Amplitude and Phase".

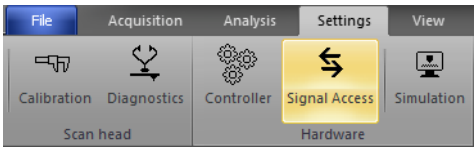
  The X-channel incorporates both sign and magnitude of the deviation.

Software settings

Before KPFM imaging can start, the control software must be adjusted to allow application of a voltage to the tip, and the phase settings of the Lock-in amplifier must be optimized. There is a Wizard that can automatically prepare the software and some of the settings for you (see *KPFM Wizard* (page 109)), but it is suggested to go through the manual procedure at least once so that you know what to adjust and optimize when you really do use the wizard.

To allow tip voltages to be set:

1. In the "Hardware" group of the "Settings" tab, select the "Signal Access" button:



❷ In the SPM Parameter dialog, which now opens with the Signal Access page, select "Voltage Source Output" as Tip Signal mode in the Signal Module Config section (see *Figure 8-10: Activating Voltage Source Output*).

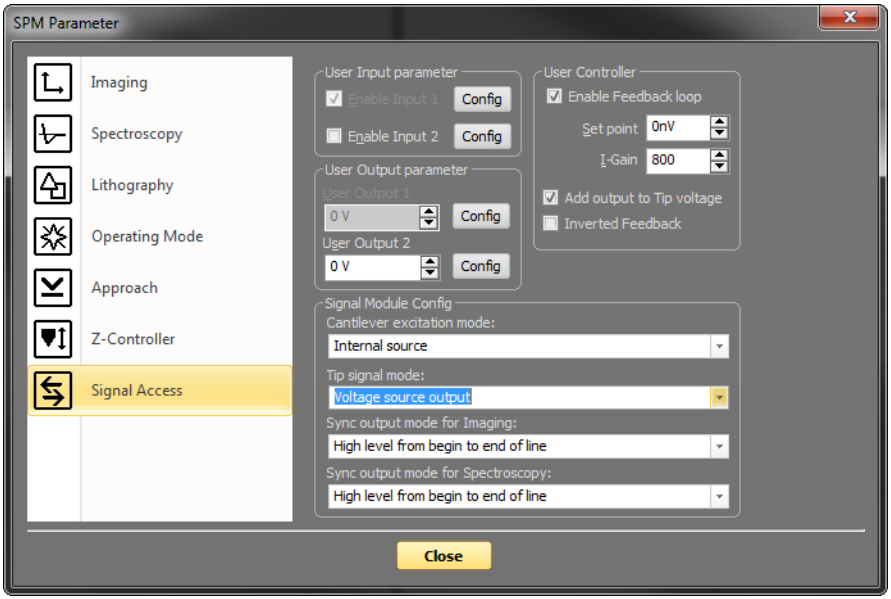


Figure 8-10: Activating Voltage Source Output

To optimize the phase settings on the lock-in amplifier:

1. Approach the sample in Dynamic Force mode with a suitable cantilever.
2. In the Mode Properties section of the Imaging window, set "Tip Voltage" to +3 V (see *Figure 8-11: Adjusting Tip Voltage*).
3. Adjust the phase on the Lock-in amplifier until the X-channel signal is maximally positive and the Y-channel signal is close to zero.
4. Return the "Tip Voltage" setting to 0 V.

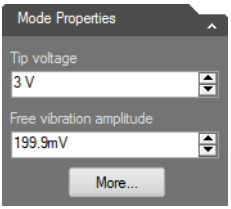


Figure 8-11: Adjusting Tip Voltage

Further optimization can optionally be carried out as outlined below (see also *Figure 8-14: Tip Voltage Spectroscopy*). This procedure will additionally give an indication of the signal variations that are to be expected in the imaging experiment.

To further optimize the phase settings of the Lock-in amplifier, perform the following steps while approached:

1. In the Signal Access page of the SPM Parameters dialog, select "Enable Input 1".
2. Configure User Input 1 and User Output 1 (see *Figure 8-12: Configuration of User Input 1 and User Output 1*) by clicking the respective "Config" buttons.

   For correct voltage display, you will need to apply the conversion that the Lock-in amplifier produces (see *Example* below).

Example

- If the X-channels output has a range equal to ±10 V, the sensitivity range of the lock-in amplifier can be inserted directly into the Calibration section of the User Signal Editor for User Input 1 (see *Figure 8-12: Configuration of User Input 1 and User Output 1*, left, which shows the calibration settings for a ±10 mV sensitivity range).
- If the X-channel output has a range different from ±10 V, the sensitivity range that would be equivalent to ±10 V should be entered. Thus, a ±10 mV sensitivity range on a ±2.5 V output range would correspond to a ±40 mV sensitivity range on a ±10 V output range.

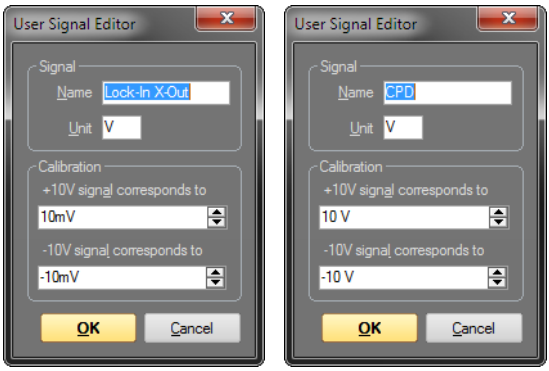


Figure 8-12: Configuration of User Input 1 and User Output 1. (Left) Suggested name and calibration settings for User Input 1; see example above. (Right) Suggested name and calibration settings for User Output 1.

❸ Make sure that "Enable Feedback Loop" in the User Controller page of the SPM Parameters dialog is unchecked.

❹ Open the Spectroscopy window (see *Figure 8-14: Tip Voltage Spectroscopy*) by clicking the Spectroscopy tab at the bottom of the Measurement pane.

❺ In the Parameters section of the Spectroscopy window, click the "More" button.

The SPM Parameters dialog will open on the Spectroscopy page.

❻ Set all parameters and settings to the ones shown in *Figure 8-13: Spectroscopy parameters*

❼ Select User Input 1 (or the name assigned to it) to be displayed in the Line graph chart (see *Figure 8-13: Spectroscopy parameters*).

❽ Adjust the phase on the Lock-in amplifier until the maximum slope is observed.

KPFM Imaging

After proper adjustment of the phase, imaging can start (see *Figure 8-15: KPFM imaging*). On Nanosurf AFMs, the KPFM signal and sample topography can be recorded simultaneously in a single scan. To operate the FlexAFM in simultaneous KPFM mode:

❶ In the Mode Properties section of the Imaging window, make sure that "Tip Voltage" is set to 0 V.

❷ Set all Signal Access parameters and settings to the ones shown in *Figure 8-10: Activating Voltage Source Output* (page 103).

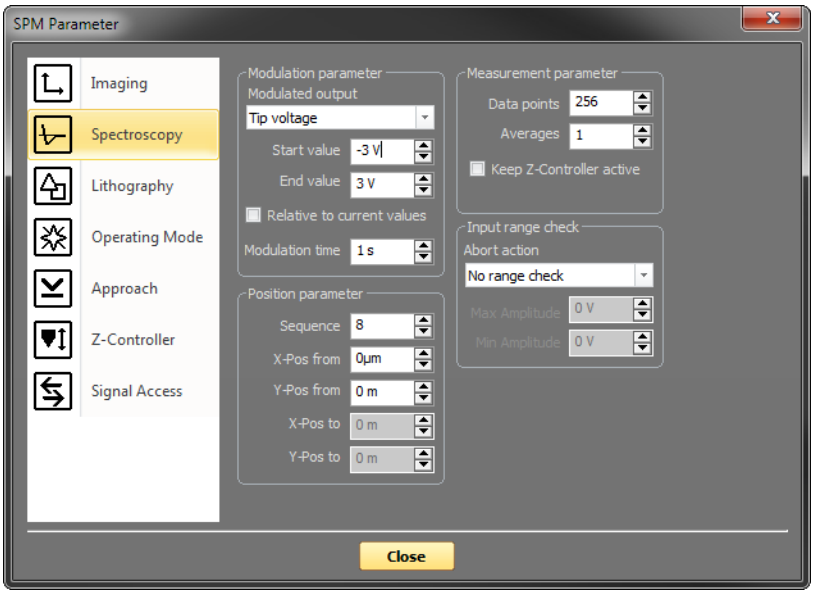


Figure 8-13: Spectroscopy parameters

❸ Configure User Output 1 (see *Figure 8-12: Configuration of User Input 1 and User Output 1*, right).

❹ In the User Controller section of Signal Access page of the SPM Parameters dialog, check or uncheck the "Inverted Feedback" option (see also *Figure 8-10: Activating Voltage Source Output* (page 103)).

The correct setting depends on the settings and type of Lock-in amplifier. If set incorrectly, the feedback responds in the wrong direction and the output voltage will go to its maximum or minimum value. When this happens:

➔ Change the status of the "Inverted Feedback" check box.

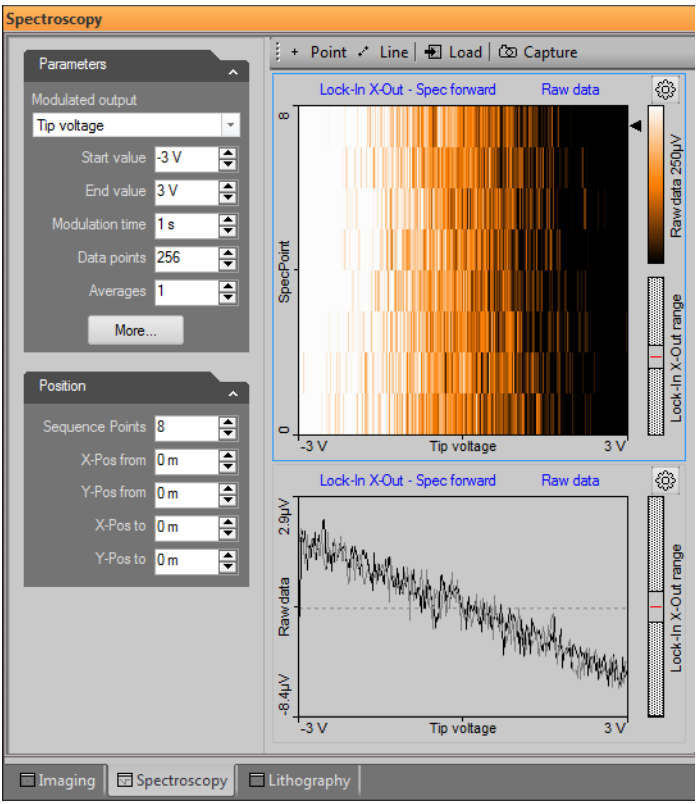


Figure 8-14: Tip Voltage Spectroscopy. The phase optimization procedure. The "Tip voltage" setting (Mode Properties section of the Imaging window) is ignored during running of the voltage ramps. In the example shown here, a sequence of 8 curves was recorded to allow an easy comparison between the individual curves.

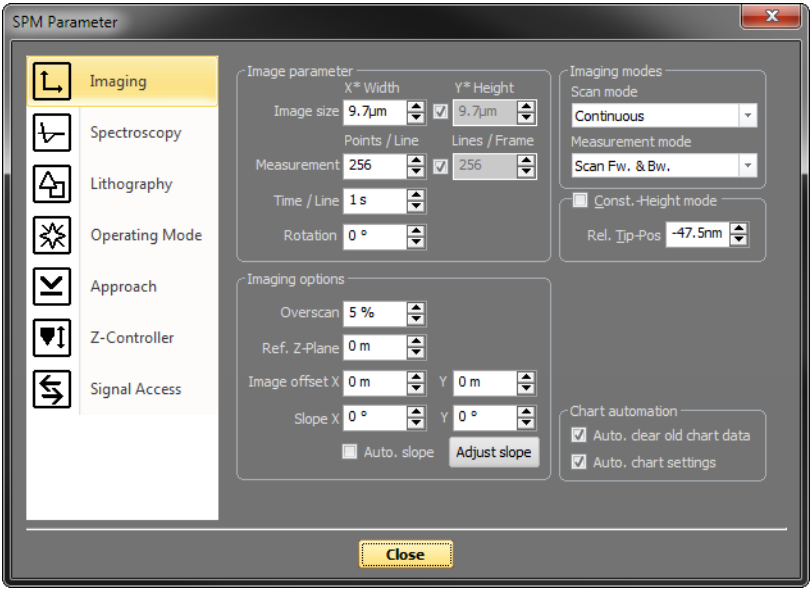


Figure 8-15: KPFM imaging. Settings during measurement.

Tip:

If signals are not as expected, the applied voltage can be checked with a multimeter. The tip voltage specified in the software should be directly measurable on the cantilever chip or spring. One test lead of the multimeter is pressed gently onto the cantilever chip, while the other is connected to the ground.

CAUTION

The test lead on the cantilever chip must be put on with great care, as excessive force on the chip will cause damage to the cantilever holder, optical unit or approach mechanism!

Tip

Upon request, a parameter file for KPFM measurements can be obtained from Nanosurf's Support department.

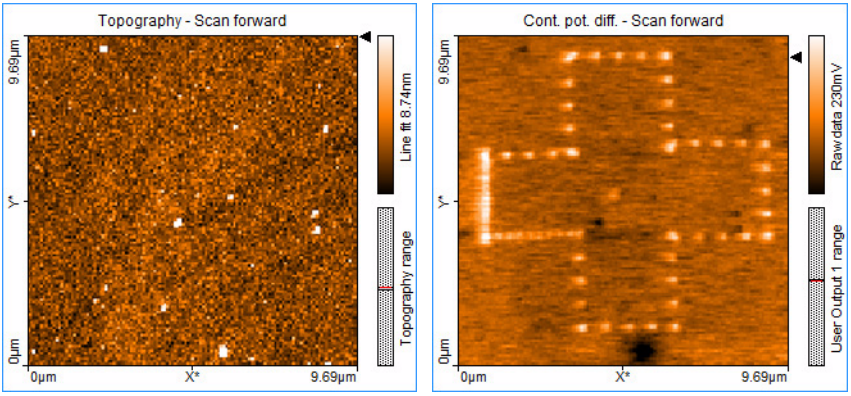
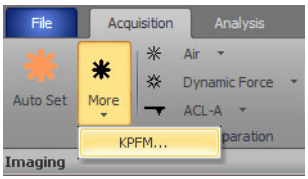


Figure 8-16: KPFM measurement. Topography (left) and KPFM signal (right) of local charges that were placed on an insulating (oxide) surface layer in a "Swiss cross" pattern. Image courtesy: Marcin Kisiel, Thilo Glatzel and students of the Nanocurriculum of the University of Basel.

KPFM Wizard

As mentioned earlier, a KPFM wizard exists, which can set many of the parameters and settings for you, although the optimization processes described above will remain to be performed. To start the wizard:

❶ In the Preparation group of the Acquisition tab, Select "KPFM" from the drop-down menu of the "AutoSet" button:



The wizard dialog will open.

❷ Follow the instructions of the wizard.

Alternative measurement procedure

As an alternative to the simultaneous measurement procedure described above, a sample can also be scanned twice: once for topography and a second time in constant height mode for the contact potential image (see also technical note *TN00031 – MFM*). Although the quantitative determination of the local work function can potentially be enhanced by constant height measurements, it has two main disadvantages:

1. The same scan area must be scanned twice, thereby consuming more time.
2. A lateral mismatch between the topography and KPFM images may occur as a result of drift or vertical movement.

These disadvantages do not occur during simultaneous collection of the topography and surface potential data. In addition, the lateral resolution of the KPFM signal is improved when recording all data in parallel, because the tip and sample can be kept at a smaller distance throughout the experiment. Nanosurf therefore recommends the simultaneous measurement procedure for KPFM.

8.10: Scanning Thermal mode

Scanning Thermal Microscopy is an AFM imaging mode that maps changes in thermal conductivity across a sample's surface. Similar to other modes that measure material properties (LFM, MFM, EFM, etc.), SThM data is acquired simultaneously with Topographic data. The SThM mode is made possible by replacing the standard contact mode cantilever with a nanofabricated thermal probe with a resistive element near the apex of the probe tip. This resistor is incorporated into one leg of a Wheatstone bridge circuit, which allows the system to monitor resistance. This resistance correlates with temperature at the end of the probe, and the Wheatstone bridge may be configured to either monitor the temperature of a sample or to qualitatively map the thermal conductivity of the sample.

8.10.1: SThM measurements

Changes in sample temperatures are often measured on active device structures. For example, it is possible to image hot spots and temperature gradients on devices such as magnetic recording heads, laser diodes, and electrical circuits. Thermal conductivity imaging, however, is commonly applied to composite or blended samples. In this mode, a voltage is applied to the probe and a feedback loop is used to keep the probe at a constant temperature. As the thermal probe is scanned across the sample surface, more or less energy will be drained from the tip as it scans across different materials. If the region is one of high thermal conductivity, more energy will flow away from the tip. When this occurs, the thermal feedback loop will adjust the voltage to the probe to keep it at a constant temperature. When the probe moves to an area of lower thermal conductivity, the feedback loop will lower the voltage to the probe, as it will require less energy to keep the probe at a constant temperature. By adjusting the voltage to keep the probe temperature constant, a map of the sample's thermal conductivity is generated. Having a smooth surface will minimize changes in the SThM contrast that result from topographic effects.

8.10.2: Nano-TA measurements

Beyond adding the extended capabilities of SThM imaging, it is also possible to acquire local quantitative thermo-mechanical information with sub-100-nm resolution. This is

possible with the nano-TA option offered by Anasys Instruments. Once an area of thermal interest has been identified using standard Topography imaging with the thermal probe, it is then possible to place the probe at a specific point to measure local thermal properties. This information is obtained by linearly ramping the temperature of the nano-TA probe with time while monitoring deflection of the probe. The thermo-mechanical response allows the user to obtain quantitative measurements of phase transition temperatures such as melting point (T_m) and glass transition temperatures (T_g). This produces a plot of probe deflection as a function of temperature. At the point of these phase transition temperatures, the sample beneath the probe will soften, allowing the probe to penetrate into the sample. This breakthrough in spatial resolution of thermal properties has significant implications in the fields of Polymer Science and Pharmaceuticals where understanding local thermal behavior is crucial.

8.10.3: System requirements and procedures

System requirements

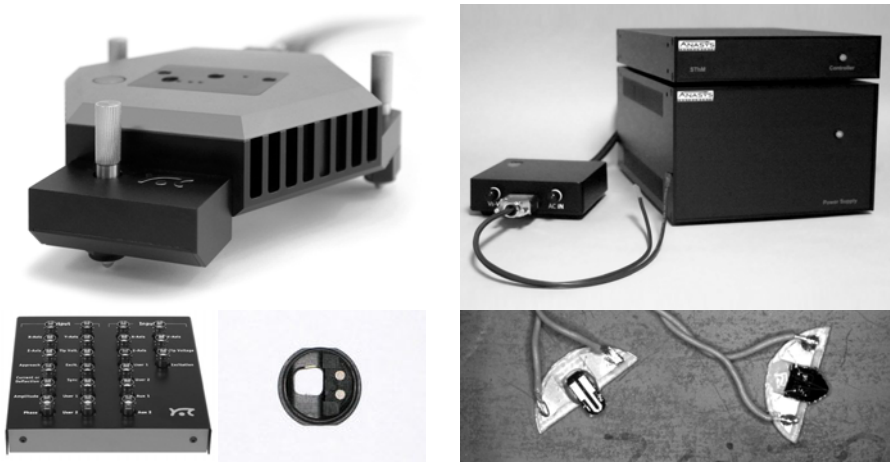


Figure 8-17: Components required for Scanning Thermal measurement modes. (Left) Nanosurf components: FlexAFM Scan Head, Signal Module A, Cantilever Holder ST. (Right) Anasys components: SThM electronics (comprising the power supply, controller, and CAL box) and Thermal probes

The Easyscan FlexAFM with Signal Module A and Cantilever Holder ST is required to perform SThM imaging and/or local nano-TA sample analysis (see *Figure 8-17: Components required for Scanning Thermal measurement modes*, left). Anasys Instruments provides hardware and software that easily integrate with the FlexAFM system. Anasys thermal probes are premounted on supports (*Figure 8-17: Components required for Scanning*

Thermal measurement modes, right) that are compatible with the FlexAFM Cantilever Holder ST. The Anasys SThM system (*Figure 8-17: Components required for Scanning Thermal measurement modes*, right) includes a simple software interface that controls the thermal analysis electronics via a USB connection. This interface is capable of outputting a low-noise, high-resolution voltage to the probe. The voltage may be varied over a wide range depending on the probe type and the desired temperature of the probe (<0.1°C resolution). The other components in the bridge circuit are easily changed if required for custom experiments, and the system includes an input connection to apply AC voltages to the probe. The resistance of the probe is output on a BNC, which is then connected to User Input 1 on the Easyscan 2 Signal Module A. For SThM imaging, the control software is configured to collect the resistance data on User Input 1, allowing SThM information to be recorded and displayed as a chart in the imaging window of the control software. During nano-TA experiments, the Anasys software allows the User to set Nano-TA2 controller parameters such as heating rates and temperature range. Typically, AFM feedback is turned off during the acquisition of nano-TA data.

Procedures

To operate the FlexAFM in the Scanning Thermal mode:

1. Set up the hardware as described in Technical Note "TN00475 — How to operate the Easyscan 2 FlexAFM with Anasys thermal probes" (contact Nanosurf Support for details).

   Good results were obtained with Anasys GLA-1 and AN2-200 probes.

2. In the Preparation group of the Acquisition tab, select the Dynamic Force operating mode.

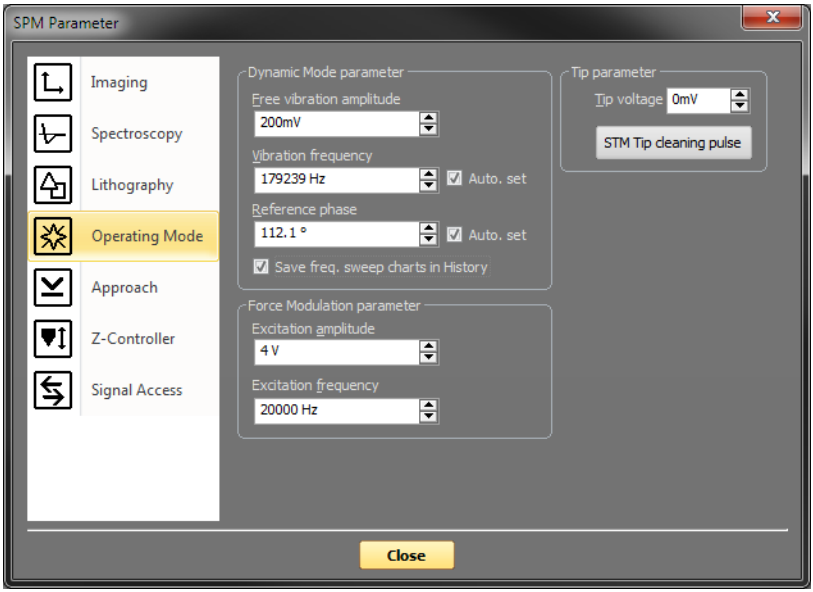
3. Set the Z-Controller parameters to appropriate values for the measurement.

4. In the "User Input parameter" section of the Signal Access page of the SPM Parameters dialog (opened by clicking the "More" button in any of the section of the Imaging window), check the "Enable User Input 1" checkbox.

5. Configure User Input 1 as required (see *Section 14.9: User Signal Editor dialog* (page 263)).

8.11: SPM Parameters dialog

8.11.1: Operating Mode page



Dynamic Mode parameters

Free vibration amplitude
The desired reference amplitude of the cantilever vibration. The cantilever vibrates at this amplitude when it is far away from the sample. The excitation strength is adjusted so that this vibration amplitude is reached.

Vibration frequency
The frequency at which the cantilever vibrates during the measurement. This frequency can be set automatically as described at the start of this section. When "Auto set" is enabled, the Vibration frequency is automatically set. Immediately at activation and each time an approach is started. When "Auto set" is disabled, the frequency can be set manually, either by directly changing its value in the control box, or by using the Vibration Frequency Determination dialog (see *Section 8.13: Vibration Frequency Search dialog* (page 120)).

Reference Phase
The reference phase for the detected cantilever vibration. Changing the reference phase changes the offset of the phase signal. The phase reference can be automatically set so that

the phase signal is zero. When “Auto set” is enabled the phase reference is automatically set after finishing the approach.

Force Modulation parameters

Excitation amplitude
The amplitude of the sensor excitation during a force modulation mode measurement.

Excitation frequency
The frequency of the sensor excitation during a force modulation mode measurement.

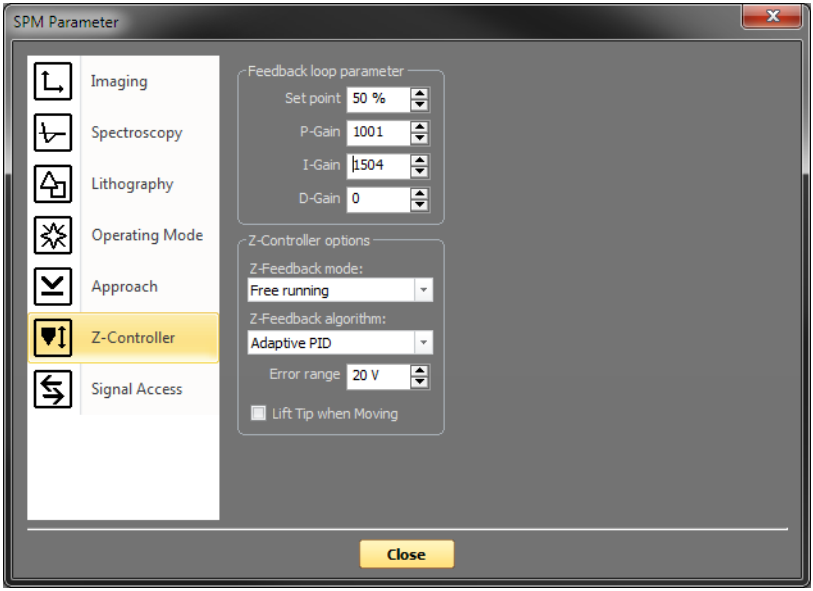
Tip Parameter

Tip Voltage
This parameter defines the potential to be applied to the tip. The voltage that can be used lies between -10V and +10V.

Info:

With the STM scan head the sample is automatically connected to the ground of the instrument. With AFM scan heads the sample has to be electrically connected to the instrument chassis ground for accurate measurements.

8.11.2: Z-Controller page



Feedback loop parameter

Setpoint
The working point for the Z-Controller. Depending on the operating mode, this is the tunneling current (STM mode), cantilever deflection (Static Force mode) or relative cantilever vibration amplitude (Dynamic Force mode). In the later case, the set amplitude is relative to the operating amplitude, set in the Mode Properties Section. For example, when a Setpoint of 70% is used, the Z-Controller will move the tip closer to the sample until the vibration amplitude has decreased to 70% of the vibration amplitude far away from the sample.

P-Gain
The strength of the Z-Controller reaction that is proportional to the error signal. Increasing the P-Gain decreases the error signal.

I-Gain
The strength of the Z-Controller reaction that is proportional to the integral of the error signal. Increasing the I-Gain decreases the error signal over time. It is the least sensitive to noise, and usually the dominant contributor to the topography measurement.

D-Gain
The strength of the Z-Controller reaction that is proportional to the derivative of the error signal. Increasing the D-Gain decreases fast changes in the error signal, but also amplifies high frequency noise.

Z-Controller options

Z-Feedback Mode
The following modes are available:

- **Free Running**
  The Z-Controller is active.
- **Freeze Position**
  The Z-Controller is not active, the scanner remains in its current Z-position.
- **Stop and Clear**
  The Z-Controller is not active, the scanner is moved to the "Ref. Z Plane", set in the Imaging page of the SPM Parameters dialog. The Probe Status Light will blink green as long as the Z-Controller is deactivated.

CAUTION

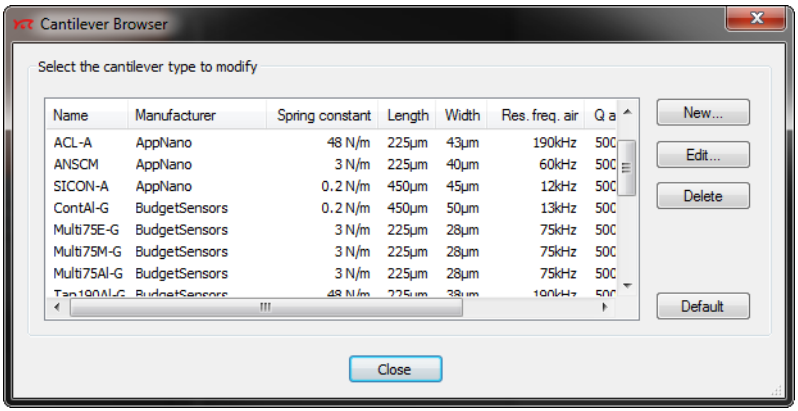
The tip may be damaged when the Z-Controller is not active during scanning. This will happen when Ref. Z Plane is much lower than the current position of the tip, or when the scan range contains large height differences.

Z-Feedback algorithm
The following algorithms are available:

- **Standard PID**
  A standard PID controller is used for Z-Feedback.
- **Adaptive PID**
  A standard PID controller is used for Z-feedback. In addition, the bandwidth of the Topography measurement is adapted to the number of measured points per second. The adaptive PID controller thus reduces noise in the measurement. However, topography changes that happen faster than the time between two measured points are also lost. This makes it more difficult to detect vibrations due to instability of the feedback loop. These vibrations remain visible in the Current, Amplitude, or Deflection signal, however, so always monitor these signals when optimizing Z-Controller settings, especially when using the Adaptive PID.

Error Range
The range of the error signal used to control the Z-Position. The error signal is the difference between the signal used for topography feedback and the current Setpoint. When the value of "Error Range" is reduced, the resolution of the error signal is increased.

8.12: Cantilever Browser dialog



The Cantilever Browser dialog displays the list of stored cantilever types in the database of the SPM Control Software. In this database, many cantilevers of different manufactures are saved with their typical physical properties. The Cantilever Browser dialog is opened via the drop-down menu entry “Cantilever browser” of the “cantilever” button in the Preparation group of the Acquisition tab.

New...
Opens the Cantilever Editor dialog for a new cantilever type. You can create new cantilever types that are not defined in the default configuration. See section x.1 The Cantilever Editor

Edit...
Opens the “Cantilever Editor” dialog to modify the currently selected cantilever type. See section x.1 The Cantilever Editor

Delete
Deletes the currently selected cantilever type.

Default
Sets all known cantilevers types back to their default factory settings. It also restores deleted known cantilevers. After a software update, new known cantilevers are added. User defined cantilevers are always kept as defined.

Attention:

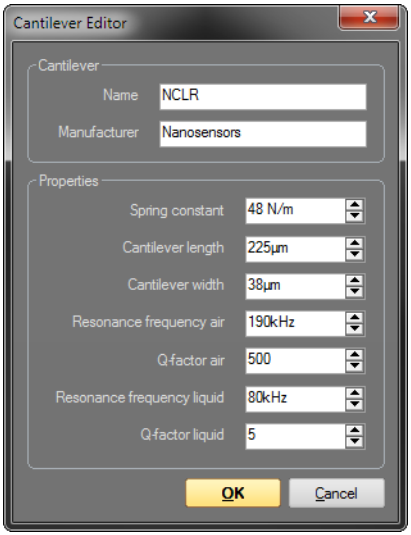
Please note that scan heads with cantilever holders based on the Alignment Chip technology can only be used with cantilevers possessing the following properties:

- The sensor chip must have grooves that fit onto the alignment chip.

Attention:

- The cantilever should have a nominal length of 225 µm or more, and a top width of 40 µm or more (please distinguish between mean width specified by most manufacturers and the actual top width of trapezoid-shaped cantilevers).
- The back of the cantilever must have a coating that reflects infrared light. Uncoated cantilevers transmit much of the infrared light of the cantilever deflection detection system.

8.12.1: Cantilever Editor dialog



The Cantilever Editor dialog allows and editing of existing cantilever types and the creation of new cantilever types that are not defined in the default configuration.

Cantilever

Name
Name of the cantilever type. This name appears in the Cantilever type drop-down menu in the Preparation group of the Acquisition tab. The list is sorted by the manufacturer's name.

Manufacturer
Name of the cantilever manufacturer.

Properties

Spring constant
This parameter defines the nominal spring constant of the cantilever type. This value is used to calculate the correct force used for Z-Controller Setpoint and chart signals in all operating modes that use the Static Force for Z-control.

IMPORTANT

The deflection calibration value of the current scan head calibration file is used to calculate the force:

*Force [N] = Spring Constant [N/m] * Deflection [m]*

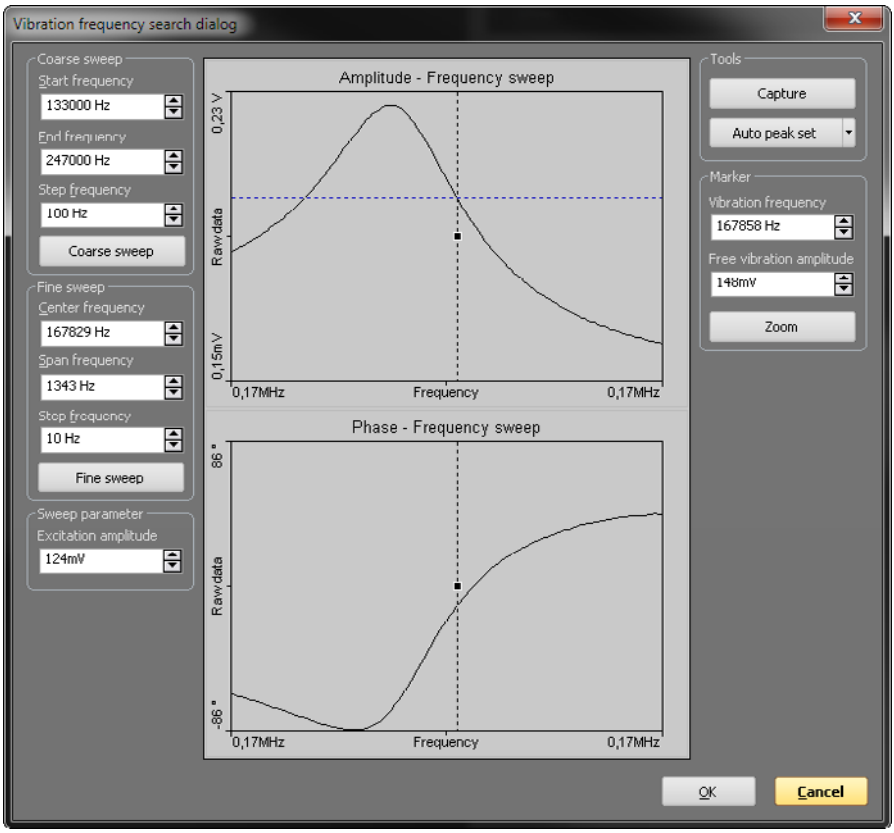
Cantilever length
The nominal length of this cantilever type (for information only, currently not used by the control software).

Cantilever width
The mean width of this cantilever type (for information only, currently not used by the control software).

Resonance frequency air / Resonance frequency liquid
The nominal resonance frequency of the cantilever type in air or in liquid measurement environment. This frequency is used for calculation of the automatic coarse frequency sweep search range (see *Section 8.13: Vibration Frequency Search dialog* (page 120)).

Q-factor air / Q-factor liquid
The apparent quality factor of the cantilever in air or in liquid measurement environment. The higher the number, the sharper the peak. By default, this number is 500 in air and 5 in liquid. The quality factor is used for calculation of the automatic fine frequency sweep search range (see *Section 8.13: Vibration Frequency Search dialog* (page 120)).

8.13: Vibration Frequency Search dialog



8.13.1: General concept

The Vibration Frequency Search dialog provides all functionality to view, search and change the vibration frequency used by the dynamic measurement modes. It is opened by clicking the “Freq. Sweep” button in the Preparation group of the Acquisition tab. When opened, the previous frequency sweep is shown. If no previous sweep was performed, the charts are empty.

To find the cantilevers best operation frequency the control software measures a so called Bode-Plot. This Bode-plot displays the cantilevers amplitude and phase response versus excitation frequency. Based on this Bode-plot, the SPM Control Software is able to

automatically detect the cantilever resonance peak and adjust the operating frequency accordingly. In some cases (mostly in Liquid environment) it is necessary for the user to adjust the operating frequency manually (based on the Bode-plot result), because the automatic algorithm is not able to find the right frequency peak.

For recording the Bode-plot, the SPM Control Software tunes the cantilever excitation from a start frequency slowly up to a higher frequency. During this tuning (or sweeping) the cantilevers amplitude and phase response is measured and saved. The result is plotted in an Amplitude and a Phase versus Frequency chart. The Excitation amplitude is held constant during the sweep. Therefore, any change in detector amplitude and phase signal is a result of cantilever response.

Resonance frequencies vary greatly between cantilevers, depending on the cantilever's respective physical properties. Cantilever manufacturers provide information on the resonance frequency range of each cantilever type. The SPM Control Software therefore has a built-in database of commonly used cantilevers. Other cantilever can be manually added by the user (see *Section 8.12: Cantilever Browser dialog* (page 117)). Based on this database information, the control software selects the frequency sweep range.

After a coarse and a fine sweep, the optimal operating frequency is chosen close to the resonance frequency of the cantilever.

IMPORTANT

The Phase measurement and chart plot is performed only if a Mode Extension Module is installed in the SPM controller. The Phase is always measured, independent on the selected Operating Mode.

8.13.2: Automated vibration frequency search

Tools

Auto frequency set

A click to this button starts an automated vibration frequency peak search and optimization procedure. This procedure consists of four phases:

1. First a coarse frequency sweep based on the database information of the currently selected cantilever is performed. The frequency range of this sweep is shown in the coarse sweep section.
2. Based on the best frequency peak found in this coarse sweep a narrow band fine sweep is done. The frequency peak and sweep range used for the fine sweep is shown in the fine sweep section.
3. Based on the amplitude reduction settings (accessed by choosing "Config..." from the "Auto frequency set" buttons drop-down menu) the optimal vibration frequency is

selected and the excitation amplitude tuned to get the desired free vibration amplitude at this frequency.

4. After the amplitude tuning, a final fine sweep is performed with the new excitation amplitude.

At the end of the procedure, the new operating frequency is shown by the marker (both graphically and in numbers). Additionally, the "excitation amplitude" parameter shows the amplitude required to obtain the desired free vibration amplitude.

The user may now just leave the dialog and accept the new frequency using the "OK" button, reset to previous values with the "Cancel" button, do manual adjustment with the marker, or change amplitude settings and/or customize frequency sweep ranges through use of the edit boxes and action buttons.

Capture
Stores a copy of the current Bode-plot in the History page of the Gallery panel. The data is stored as a new measurement and remains open in the Document space of the SPM Control Software.

Config...
Selected from the "Auto frequency set" button's drop-down menu, this menu option opens the Auto frequency config dialog (see *Section 8.13.4: Auto Frequency Config dialog* (page 124)).

8.13.3: Manual sweep controls

Marker

The marker represents the currently selected frequency. It is shown as a dotted vertical line in the amplitude and phase chart. The corresponding "Vibration frequency" and "Free vibration amplitude" values (see below) are shown as automatically updating numbers in the Vibration frequency and Free vibration amplitude edit boxes as well.

To move the marker by mouse, click and hold the line's handle (small black box in the center of the line) and move it around. The vibration frequency is updated immediately during the movement. At release of the marker the amplitude is measured and drawn as a horizontal line in the amplitude chart and its value is displayed in the Free vibration amplitude edit box.

To use the currently shown frequency as the new vibration frequency, leave the dialog with the "OK" button.

Vibration frequency
This parameter shows the frequency at the marker's position. It is used as the actual vibration frequency during operation of the microscope in the Dynamic operating modes. The value of this frequency can be changed manually by typing in the desired value, by

using the arrow keys beside the parameter field, or by dragging the frequency marker line in the charts as described above.

Free vibration amplitude
This parameter shows the actual amplitude at the current marker frequency. If the user enters a new value, the excitation amplitude is adjusted to obtain a free cantilever amplitude with this new value. A new frequency sweep is immediately performed and its results displayed. If the desired amplitude could not be set, an error dialog is shown.

Zoom
A click on this button starts a new frequency sweep with a smaller frequency range than currently displayed in the charts. The center of the sweep is at the markers position. The new sweep range and center position is shown in the Fine sweep parameter section.

Coarse sweep

Start / End Frequency
These parameters defines the sweep range of a coarse frequency sweep. This range is normally set large enough to search for the initial resonance peak. "Auto frequency set" sets these parameters to the range found in the Cantilever database for the currently selected cantilever.

Step Frequency
This parameter defines the frequency steps used during the sweep. Therefore, the number of data points of the sweep is defined as:

$$Datapoint = (End - Start) / Step.$$

Typical step sizes during a coarse sweep are 100 Hz or more.

Coarse s weep
The "Coarse sweep" button performs a coarse frequency sweep according to the coarse sweep parameters entered (see above).

Fine sweep section

Center / Span Frequency
These parameters defines the sweep range of a fine frequency sweep. The range is normally smaller than the coarse sweep range. "Auto frequency set" sets the center frequency to the resonance peak found during the coarse sweep. The span is set according to the quality factor found in the Cantilever database for the currently selected cantilever. Span defines the start and end frequencies for the fine sweep as follows:

$$Start = Center - (Span / 2)$$

$$End = Center + (Span / 2)$$

Step Frequency
This parameter defines the frequency steps used during the sweep. Therefore, the number of data points of the sweep is defined as:

$$Datapoints = (End - Start) / Step.$$

Typical steps are 10 Hz or less.

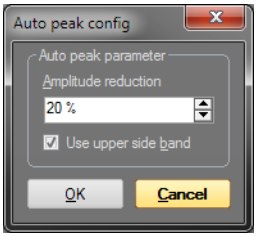
Fine sweep
The "Fine sweep" button starts a fine frequency sweep according to the fine sweep parameters entered (see above).

Sweep parameter section

Excitation amplitude

This parameter defines the used excitation amplitude during the sweep. If the user enters a new value a new frequency sweep is immediately performed and its results displayed. The "Auto frequency set" sets this value to a predefined value according to the scan head calibration file settings and the currently selected environment parameter.

8.13.4: Auto Frequency Config dialog



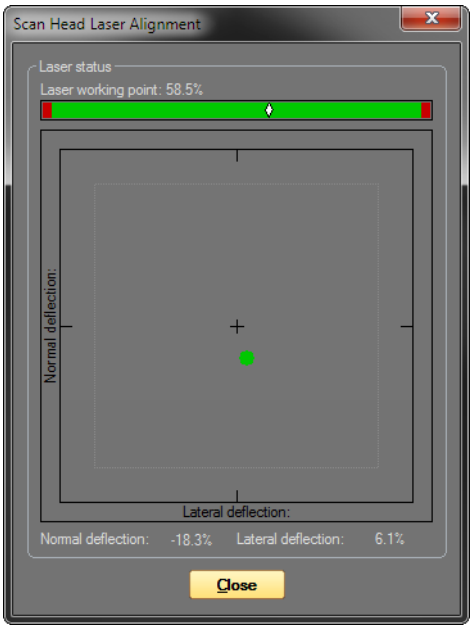
Auto frequency parameters

Amplitude reduction
This parameter defines the final position of the automated operating frequency search. Normally, the operating frequency is not at the resonance peak but somewhere beside it. "Auto frequency set" adjusts the free vibration frequency in such a way that the cantilever vibration amplitude is smaller than the vibration amplitude at the resonance frequency as defined by this parameter:

$$Amplitude_{Vibr.\ freq.} = Amplitude_{Res.\ freq.} \times (1 - Amplitude\ reduction/100)$$

Use upper side band
When checked, the vibration frequency is set to a frequency higher than the resonance frequency. When unchecked, the vibration frequency is set to a frequency lower than the resonance frequency.

8.14: Laser Alignment dialog



The Scan Head Laser Alignment dialog displays the current position of the AFM laser spot on the detector and the used laser power. It is only available when a Nanosurf FlexAFM scan head is attached. The dialog is opened by clicking the "Laser align" button in the Preparation group of the Acquisition tab.

Laser working point
This graph shows the efficiency of the laser detection system. A small white diamond-shaped marker should be found anywhere within the green area, meaning that a sufficient amount of the laser signal is being reflected by the cantilever and correctly makes it back to the photodiode detector.

If the marker resides in the red area to the right, it will turn red too, signaling that too little laser light is being detected. This can be caused by a misaligned cantilever, or by something blocking the optical path of the laser.

If the marker resides in the red area to the left, too much light is being detected by the photodiode detector, usually caused by strong environmental light. This condition is very rare, however.

Laser position
This graphical area shows where the deflected laser beam hits the photodiode detector. A green spot anywhere within the area enclosed by the dotted square means that the cantilever deflection detection system (consisting of laser, cantilever, and detector) is properly aligned. If the laser spot falls outside this area, it will become red, meaning that the alignment does not allow proper measurements to take place. Usually this is caused by a misaligned cantilever, which can be easily corrected. The position of the laser spot is also given as a percentage of the maximum deflection the detector can identify.

CHAPTER 9:

Positioning

9.1: Introduction

Positioning of the sample with respect to the tip is a prerequisite for starting any measurement. This process consists of two distinct steps:

1. An area of interest has to be found and positioned directly underneath the tip before an approach and subsequent measurement can be initiated. Several panels of the Info pane can assist with this process. They are explained in *Section 9.2: Video panel*, *Section 9.3: Online panel*, and *Section 9.4: Stage panel*.
2. The tip has to approach the sample until a given setpoint is reached. The approach step is controlled through the Approach group of the Ribbon's Acquisition tab (see *Section 9.5.1: Approach group*).

9.2: Video panel

The Video panel displays the available video signals. Each of the graphical sections used for this contains a toolbar with control options to adjust the display properties of the respective video signal. The settings for each of these controls is stored independently for each video signal (i.e. different setting can be set for both top and side view).

INFO

If your system is not equipped with a Video Camera or the SPM Controller is not equipped with a Video Module, this Panel will not be available.

9.2.1: Analog video camera display

If your system is equipped with analog cameras and the analog video module (e.g. Easyscan 2 AFM), only one camera view can be displayed at any given time.

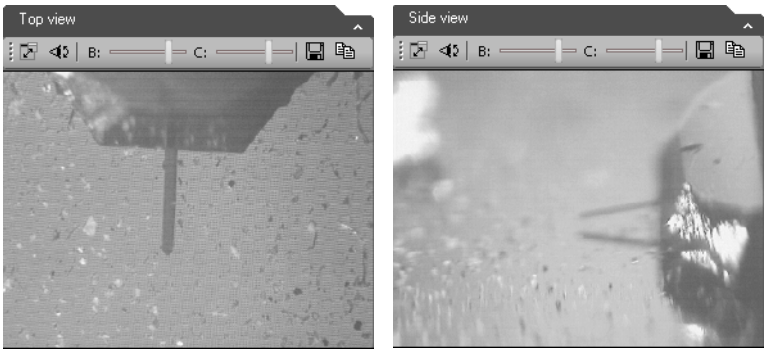


Figure 9-1: Analog video signal in the Video panel. (Left) Top view. (Right) Side view.

Analog Video Camera toolbar

Show Window
The "Show Window" button ( ) allows you to switch between display of the video signal in a section of the Video panel and display of the video signal in a separate window (see *Figure 9-2: Free floating video window*).

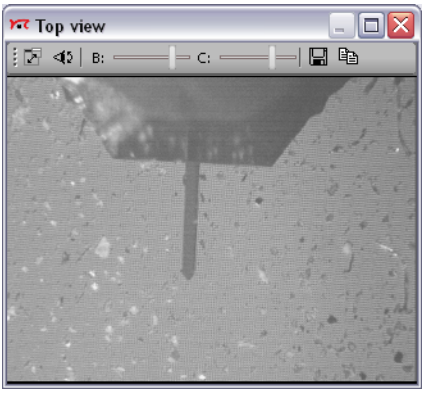


Figure 9-2: Free floating video window

Switch view
The "Switch View" button ( ) allows you to switch between the two analog video cameras. Either the Top view signal or the Side view signal is displayed.

Brightness
The "Brightness" slider ( ) regulates the brightness of the video display.

Contrast
The "Contrast" slider ( ) regulates the contrast of the video display.

Save As...
The "Save As..." button ( ) allows you to save the current video image as a JPG file.

Copy
The "Copy" button ( ) allows you to copies the current video image to the Windows Clipboard for "pasting" into other applications.

9.2.2: Digital Video Camera display

If your system is equipped with a digital USB camera (e.g. for FlexAFM or NaniteAFM scan heads), two camera views can be displayed simultaneously and more video controls are

available when compared to the analog camera options. The digital video cameras support digital Zoom and Focus adjustment via additional toolbar buttons, and an anti-moiré and a high-resolution mode are available too (see below).

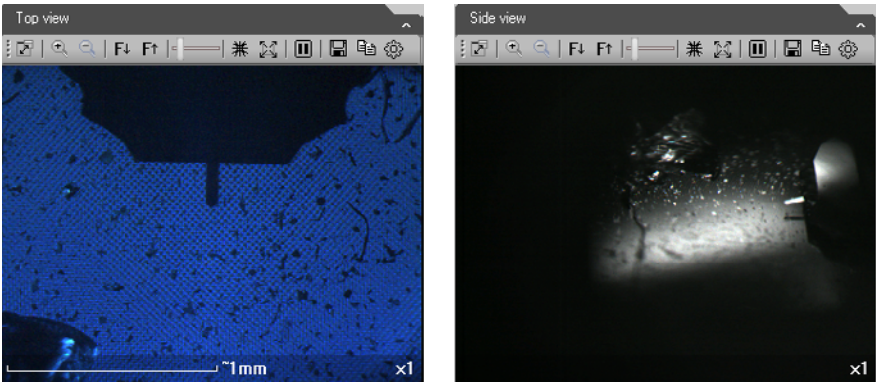


Figure 9-3: Digital video signal in the Video panel. (Left) Top view. (Right) Side view.

Digital Video Camera toolbar

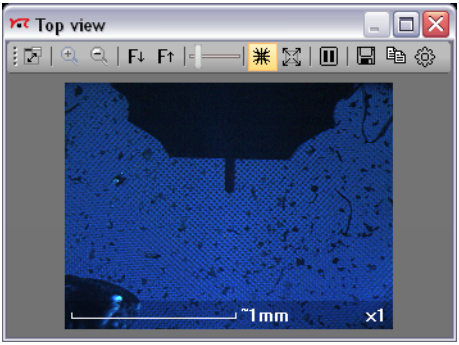
In addition to the options available for analog cameras (see *Analog Video Camera toolbar*), the following options exist:

Zoom + / Zoom –
The "Zoom" buttons ( ) allow you to zoom in or out digitally (by binning of pixels). The zoom area is always in the center of the image. The number of pixels displayed is kept constant. Therefore, the video rate is independent of the zoom factor. The current zoom factor is displayed in an overlay at the bottom of the video image.

Focus up / Focus down
The "Focus" buttons ( ) adjust the focus of the current camera view. Motors in the respective camera physically adjust lenses to change the focus plane.

Gain slider
The "Gain" slider ( ) regulates the amount of gain applied to the video signal.

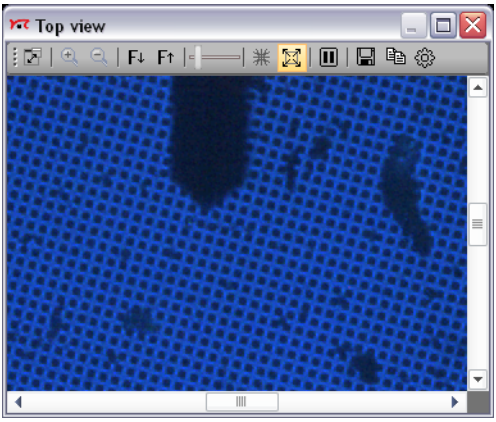
Anti-Moiré Button



The “Anti-Moiré” button ensures that the ratio between the number of camera pixels and video display pixels is always a whole number. This prevents moiré patterns from occurring in the video image. The moiré effect is mostly visible on samples with regular structures like grids or lines if this option is not enabled.

When the Anti-Moiré mode is active, the button is highlighted. Clicking the highlighted button will deactivate the Anti-Moiré mode and will cancel the button’s highlighting.

High-Resolution Mode Button



The “High-Resolution Mode” button If this mode is activated, the video display shows all camera pixels on the display one-to-one. No Zoom is available in this mode. If the video display’s pixel size is lower than the camera’s, scroll bars are automatically shown on the borders of the video display. This mode is only useful in a large separate window (e.g. on a second LCD monitor) when you need to see a sample in full detail.

When the High Resolution mode is active, the button is highlighted. Clicking the highlighted button will deactivate the High-Resolution mode and will cancel the button's highlighting.

IMPORTANT

In high-resolution mode the amount of (video pixel) data that needs to be transferred over the USB connection is huge. As a result, the video frame rate typically drops below 5 Hz and a high-performance PC is required to keep the system stable.

Pause Button
If the "Pause" button ( ) is activated the video image update is stopped and the frozen image (last frame received) is shown continuously. A second click on this button restarts the real time video display.

Video Properties Button
A click on this button opens the Digital Video Properties Dialog. See the next section (*Section 9.2.4: Digital Video Properties dialog*) for details.

9.2.3: Illumination section

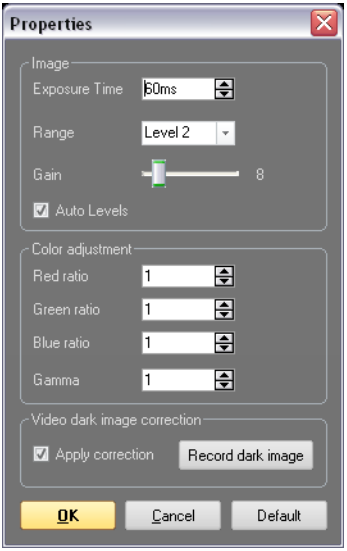
The Illumination section of the Video panel contains an Illumination slider that controls the intensity of the sample illumination LED. It may be used to adjust the amount of light on the sample, thereby optimizing the video image.

If you have an analog camera installed in your system, the illumination settings will depend on the selected camera view (top or side view) and will be stored individually.

In case you have a digital camera in your system, where top and side view are shown simultaneously, only one illumination setting is used.

If no camera is installed, the Video panel will not be accessible, and the Illumination slider will therefore be present in the Online panel (see *Section 9.3.3: Illumination section*).

9.2.4: Digital Video Properties dialog



The Digital Video Properties dialog can be accessed via the Video Display toolbar or the video display's context menu. The properties accessible through this dialog directly influence the respective camera's behavior at the camera driver level.

Image

Exposure time
Adjusts the exposure time (time to record one image frame) for the respective video camera. Changing this setting allows the camera to cope with very bright or very dark sample illumination conditions, or to fine-tune the predefined illumination condition ranges (see *Range* below).

Range
Allows the selection of different illumination ranges (levels) for quick adjustment of the video camera to the current sample illumination conditions. Lower level numbers are suitable for lower illumination conditions.

Gain
Identical to the "Gain" slider in *Digital Video Camera toolbar* (page 130), which adjusts the amount of gain applied to the video signal.

Auto Levels
When checked, this option automatically adjusts the camera data to fill the dynamic range of the Video display (similar to the "Auto set" option for the Chart data range (see *Section 13.3.2: Chart Properties dialog* (page 212)). Using this option will automatically give you a good quality image. You will find that changing the other image parameters while this option is checked (within limits) hardly has an effect on the video display anymore.

Color adjustment

Red ratio
Adjusts the relative amount of red color information in the RGB color mix for each pixel. Not available for the (monochrome) side view.

Green ratio
Adjusts the relative amount of green color information in the RGB color mix for each pixel. Not available for the (monochrome) side view.

Blue ratio
Adjusts the relative amount of blue color information in the RGB color mix for each pixel. Not available for the (monochrome) side view.

Gamma
Adjusts the midpoint of the video image's dynamic range. Adjusting this setting can be beneficial for images that show too low or too high contrast. In such cases, increase or decrease the gamma setting, respectively.

Video dark image correction

At higher gains levels, digital cameras tend to exhibit differences in intensity for individual image pixels, making some pixels stand out unfavorably from the rest. Applying the Video dark image correction (on by default) will remove any such pixels from the video display. This is done by using a so-called "dark image" as a reference. The SPM Control Software will attempt to record this dark image the first time it is started with the FlexAFM Video Camera attached. This process is silent. If successful, the "Apply correction" checkbox (see below) will be available in the Video Display Properties dialog. If the ambient light is too high, however, the process will fail, and the "Apply correction" checkbox will be grayed out. To activate the checkbox, it will be necessary to record the dark image manually by clicking the "Record dark image" button. If the light levels are still too high, you will be advised to cover the instrument or darken the room.

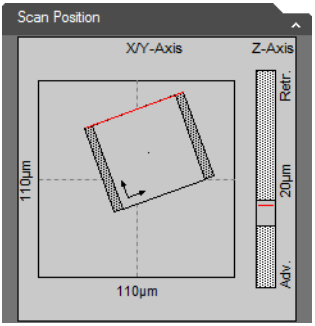
Apply correction
Applies the dark image correction.

Record dark image
Records the dark image for video correction. Each time this button is clicked, the previous dark image reference will be overwritten.

9.3: Online panel

The Online Panel displays scan area information and various other data.

9.3.1: Scan Position section



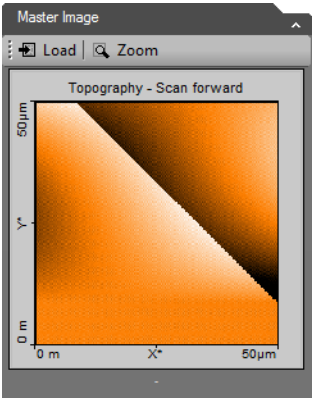
The Scan Position section displays information about the maximum scan head scan area, the current measurement area and the tip position.

The left side of the section shows the maximum scan range of the scan head (outer square and numbers) and the currently set image size (inner square). The dotted bars to the left and right of the inner square represent the "Overscan" area (see *Overscan* in *Section 10.5.1: Imaging page* (page 159)).

The red line in the inner square represents the currently measured scan line during imaging. The two arrows represent the orientation of the axes of the image coordinate system. The small dot in the center of the image square represents the Offset and Rotation point (see *Image offset X/Y* and *Rotation* in *Section 10.5.1: Imaging page* (page 159)).

The dotted bar on the right side of the Scan Position section represents the maximum Z-range (bar and numbers), the used range for the current measurement (gray box) and the actual Z-position (average of the current scan line) of the tip (red line).

9.3.2: Master Image section



The Master Image section displays a topography measurement, which can be used as a reference for comparison with other measurements, or as an overview image for multiple (zoomed) measurements on several points of interest. The Master Image section starts out blank. A reference image has to be loaded manually. When this is done, a box with a black outline will show the current measurement area inside the reference/overview image.

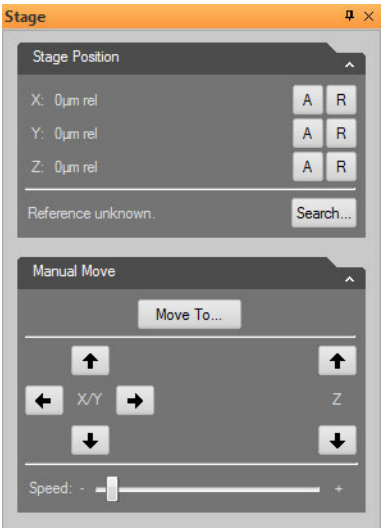
Load
The Load button captures the actual topography image of the active Measurement Tab into the Master Image Section.

Zoom
A click to this tool activates the Zoom Tool in the Master Image chart area to select a new scan area size and position (within the loaded image). After selecting the Zoom button the user draws a zoom frame in the chart area. To select the new scan area, double-click within the selection area. A right mouse click aborts the zoom operation.

9.3.3: Illumination section

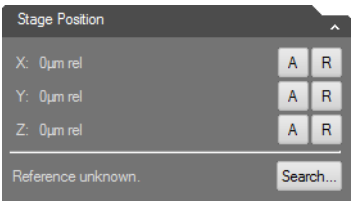
With the Illumination slider the intensity of the sample illumination LED is controlled. This slider is only present in the Online panel when no video camera is present in your system. When a camera is present, this slider automatically moves to the Video panel (see *Section 9.2.3: Illumination section*).

9.4: Stage panel



This panel is only available to Nanosurf AFM systems when the Translation Stage Software is installed on the computer that contains the SPM Control Software (usually with Nanite systems). The Stage panel allows moving of the translation stage in the same way as the corresponding panel in the Batch manager is operated.

Stage Position section



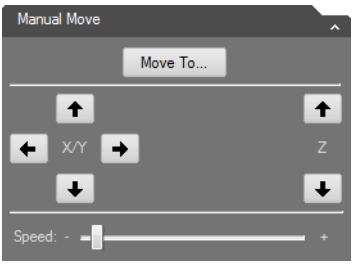
The upper part of the Stage Position section displays the current position of the translation stage in coordinates relative to the zero point of the translation stage, or in coordinates relative to a previously set zero point. On start-up, the coordinates are shown relative to the start up position, until the reference position of the stage has been found (e.g. after clicking the “Search” button).

Absolute
Clicking the "Absolute" button (A) (re)sets the zero point of this axis' coordinate display to the absolute zero point of the translation stage. The Stage Position coordinates (X,Y,Z) now display the absolute position of the stage.

Relative
Clicking the "Relative" button (R) sets the zero point of this axis' coordinate display to the current position. The Stage Position coordinates (X,Y,Z) now display the position of the stage relative to the position where the "Relative" button was last clicked.

Search
Clicking the "Search" button (Search...) starts a search for the reference position of the translation stage. The reference position can be different from the zero point of the stage.

Manual Move section



Move To
Clicking the "Move To" button (Move To...) opens the Move Stage To dialog (see *Section 9.4.1: Move Stage To dialog*).

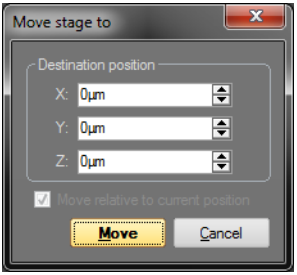
Arrow buttons
Move the translation stage in the direction of the arrow for as long as the button is clicked and held.

Speed
The speed with which the translation stage moves.

9.4.1: Move Stage To dialog

CAUTION

It is recommended to always keep the approach stage in the upper limit position. When repeatedly moving to the same position, it is possible that the tip will crash into the sample if the approach stage is in a lower position than it was before.



This dialog is only available to Nanosurf Nanite AFM systems with an automated translation stage attached and the corresponding software installed. It is used to move the translation stage to a specific destination position. It is opened by clicking the "Move To" button in the Manual Move section of the Stage panel (see *Manual Move section* (page 138)).

X/Y/Z
The (X, Y, Z) coordinate of the destination position.

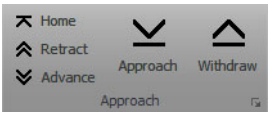
Move relative to current position
When checked, the (X,Y,Z) coordinates are interpreted relative to the current position. When not checked, the coordinates are interpreted as a position relative to the absolute zero point of the translation stage. This checkbox is only enabled when the reference position has been found (e.g. after clicking the "Search" button in the Stage Position section of the Stage panel).

Move
Clicking the "Move" button (

) moves the translation stage to the destination position entered by the user (see above).

9.5: Acquisition tab

9.5.1: Approach group



Home
Increases the tip–sample distance to its maximum value to ensure that the maximum motorized approach range is available during final automatic approach.

Retract
Increases the tip–sample distance at maximum speed until the button is released.

Advance
Decreases the tip–sample distance at maximum speed until the button is released.

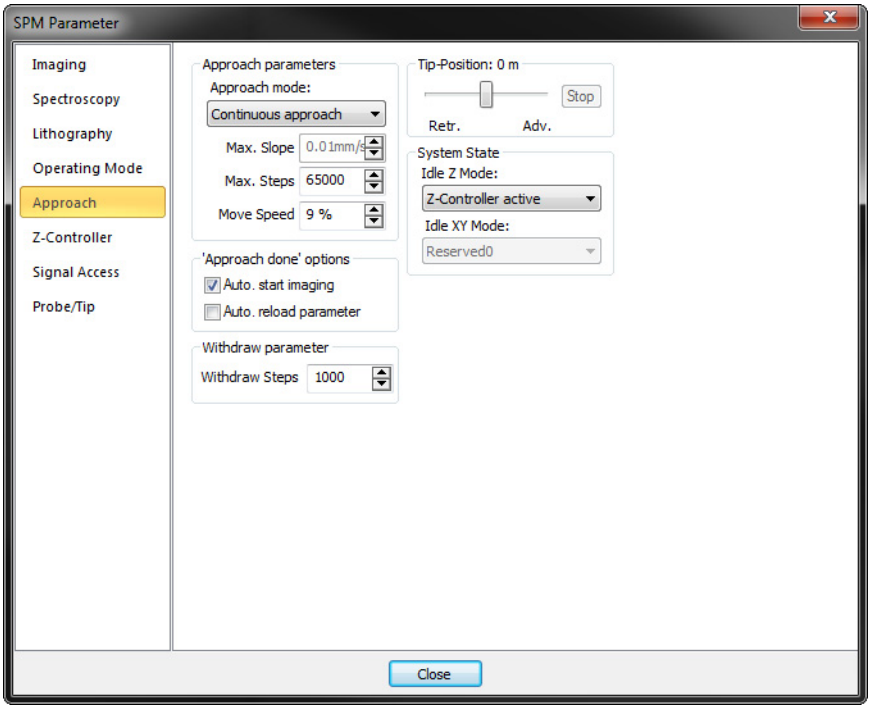
Approach
Starts the automatic approach. During automatic approach, the tip–sample distance is decreased until the Setpoint (set in the Z-Controller section) is reached, or until the maximum number of approach steps is reached (see *Section 9.6.1: Approach page* (page 141)).

Withdraw
Increases the tip–sample distance with approach speed settings.

Launcher icon
More advanced settings are available through the "Dialog Launcher" icon (at the bottom right corner of the Preparation group), which opens up the SPM Parameters dialog on the Approach page (see *Section 9.6.1: Approach page* (page 141)).

9.6: SPM Parameters dialog

9.6.1: Approach page



Approach parameter

Approach Mode

For STM scan heads no selection is possible (approach is always performed step-by-step through the stick-slip motion of the STM approach stage).

For AFM scan heads, two approach options are available for AFM:

– **Continuous approach**
  Approach with continuous slow motorized stage movement until surface contact point is reached. Z-Axis stays at Tip-Position during approach. This is the default approach method, and was the only method available in the Nanosurf SPM Control Software before version 3.

– **Step-By-Step approach**
  Approach is performed by moving the motorized stage quickly over a distance that is less than the scanner's Z-range. During the movement of the motorized stage, the tip is fully retracted. When the motorized movement is finished, the scanner extends the tip along the Z-axis to probe for the sample surface. The approach is considered done when the Setpoint (defined in the Z-Controller page of the SPM Parameters dialog, or in the Z-Controller section of the Imaging panel of the Imaging window) has been reached. If it is not reached within the Z-range of the scanner, the tip is again fully retracted and the next motorized step is performed. This process of 'step-and-probe' is repeated until the Setpoint has been reached (and approach is done). This approach method is considered to be more 'gentle' to tip and sample and should be considered for very sharp tips and/or very soft samples. In general, it does however take more time than Continuous approach.

Max. Slope
This parameter defines the speed of extending the z-axis. This parameter is only available in Step-By-Step approach mode. Slower speeds help to preserve sharp tips.

Max. Steps
This parameter defines the maximal duration of an automatic approach:

- In Continuous approach mode it defines the maximum time.
- In Step-By-Step approach mode it defines the maximum number of cycles.

Move Speed
This parameter defines the move speed during automatic approach and withdraw:

- In Continuous Approach mode this value should be small. If the approach is too fast, the tip or the sample surface can be damaged. On the other hand, the motor will not move when the move speed is too small.
- In Step-By-Step Approach mode should be around full speed. Lower values help to stop in the z-range of the scanner. On the other hand the approach time increases.

Approach done options

Auto Start imaging
When selected, the system automatically starts imaging after a successful approach. Scanning automatically stops the approach motor is moved.

Auto Reload parameter
When selected, the control software reloads the default startup parameter file for each approach.

Withdraw parameter

Withdraw Steps
The number of steps to use for withdrawing the tip from the sample (see *Withdraw* (page 140)).

Tip-Position

This value determines the Z-Position of the scanner when the approach motor stops. When the Tip-Position is changed when the tip is already approached to the sample, the motor will move the approach stage so, that the Z-Position of the tip becomes equal to the set Z-Position. When a high resolution scanner is used, the Tip-Position before approach is set to approximately +500 nm (advanced) by default. This compensates for the residual motion of the approach stage that occurs after the approach motor has stopped.

System State

Idle Z Mode
Defines the state of the Z-feedback loop while not measuring. Available options are:

- **Z-Controller active**
  Keep the Z-feedback active; the tip is tracking the sample surface.
- **Retract Tip**
  This causes the tip to be retracted to the scanner's upper-most Z-position (farthest away from the sample).

9.7: ATS Stage and TSC 3000 driver configuration

The configuration of the ATS Stage and TSC 3000 Controller is accessed through the TSC 3000 driver software. It is only required for AFM systems equipped with such stages and controllers (usually Nanite systems).

Starting the TSC 3000 driver

Usually, the TSC 3000 driver start together with the Easyscan 2 control software and will be running in the background. If this is the case, the tray icon  will be visible in the Windows Notification Area (bottom right part of the Windows desktop, also known as System Tray).

When the driver is not running:

❶ Open the Microsoft Windows "Start" menu.

❷ Select the menu item “Programs” >> “Nanosurf Translation Stage” >> “Nanosurf TSC 3000 Driver”.

The name of the menu “Programs” may vary, depending on the language of your Windows operating system.

Checking the stage configuration

To check the stage configuration:

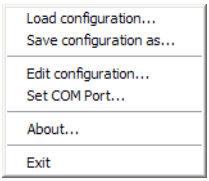
❶ Move the mouse over the icon and wait for the configuration filename to pop up.

❷ Check that the name of the stage configuration file displayed in the Window title matches the automated stage that is connected.

CAUTION

Using an incorrect stage configuration will cause the stage to behave incorrectly. This may cause damage to the system. Only change settings when instructed to do so by Nanosurf support personnel.

The driver menu



To change the TSC 3000 driver configuration and to access further driver functionality, the driver menu has to be opened. To do this:

➍ Right-click the icon in the Windows Notification Area.

TSC 3000 driver menu

Load configuration...
Allows a predefined or custom-saved configuration (“.stage” file) to be loaded into the driver software.

Once you have changed the configuration, you must search for the reference position of the stage (see *Stage Position section* (page 137) in *Section 9.4: Stage panel*).

Save configuration as...
Allows the current configuration to be saved (“.stage” file).

Save configuration as...

Allows the current configuration to be edited via the Stage Configuration dialog (see below). As with the "Load configuration option", you must search for the reference position of the stage (see *Stage Position section* (page 137) in *Section 9.4: Stage panel*) whenever changes to the stage configuration have been made.

Set COM Port...
Opens the COM Port Configuration dialog (see *Section 9.7.2: The COM Port Configuration dialog*), which allows the appropriate COM port for the TSC 3000 Controller to be set.

About
Shows the TSC 3000 driver version information in a separate dialog.

Exit
Closes the TSC 3000 driver software.

9.7.1: Stage Configuration dialog

The Stage configuration dialog reflects various properties of the ATS stage. This dialog should only be used for trouble-shooting.

CAUTION

Using an incorrect stage configuration will cause the stage to behave incorrectly. This may cause damage to the system. Only change the settings when instructed to do so by Nanosurf support personnel.

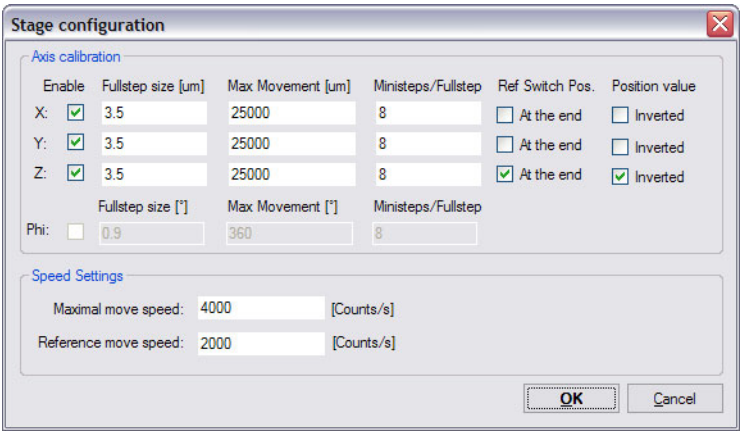


Figure 9-4: The Stage configuration dialog

Axis calibration

The axis calibration determines the relationship between the number of steps that the motor that drives a certain axis has made and the physical position coordinates of that axis. The motor controller converts the Stepcount to the position according to the formula:

$$Position\,[\mu m] = \frac{Stepcount\ from\ Limit\ \ position \times Fullstep\ size\,[\mu m]}{Ministeps\,/\,Fullstep}$$

Enable

Allows individual axis (X, Y, Z, or phi) to be enabled or disabled. Depending on the type of translation stage used and on the axes selected, the rotation axis "phi" may become available.

Fullstep size
The amount of distance that the stage travels when the stepper motor makes one step.

Max Movement
The maximum distance that the stage moves.

Ministeps/Fullstep
The number of steps in which a full stepper motor step can be sub-divided by the controller.

Ref Switch Pos.
"At the end" must be checked when the limit switch is located at the end of the translation stage's movement range (i.e., the position most distant to the motor). When checked, the controller will move the stage towards the end of the range until it finds the position of the reference switch of the stage.

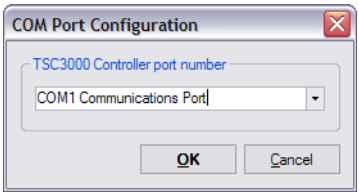
Position value
"Inverted" must be checked when the axis coordinate should decrease (rather than increase) when the stage moves towards the end.

Speed Settings

Maximal move speed:
In (Ministep)counts/second. If the Maximal move speed is set too high, the stepper motor in the stage may fail to finish a step before the TSC 3000 controller commands it to make the next one. As a consequence the stage will not be in the correct position after moving.

Reference move speed:
In (Ministep)counts/second.

9.7.2: The COM Port Configuration dialog



The TSC 3000 COM Port Configuration dialog sets the Serial Interface/COM port that the TSC 3000 Controller is connected to. The dialog is opened via the TSC 3000 Driver menu option “Set COM Port” (see *Section 9.7: ATS Stage and TSC 3000 driver configuration* (page 143)).

Chapter 10:

Imaging

10.1: Introduction

Imaging measurements of the sample are controlled using the Imaging window. This chapter describes all elements of the Imaging window in detail. For procedures describing a basic measurements, refer to *Chapter 4: A first measurement* (page 45). For details on how to use the charts see *Section 13.3: Charts* (page 209). For advanced imaging settings see *Section 10.5.1: Imaging page*.

The Imaging window is contained within the Measurement pane and can be opened by clicking the Imaging tab. The largest part of the Imaging window consists of a number of charts that display the data from the ongoing measurement: the Chart area. The imaging window can display as many charts as required. Scroll bars will appear automatically as soon as the content is larger than the window can accommodate. By default, two charts groups are displayed: 2 color maps of the sample and their corresponding line graphs. Usually, these show Topography on the left and another measurement signal on the right (e.g. Deflection), depending on the current operating mode. For more information on adding and changing charts, which basically works the same for charts in Operating windows and in stored measurements documents, see *Chapter 13: Working with documents* (page 207).

The Parameter area on the left side of the Imaging window, the so-called Imaging panel, is organized in 3 sections: the "Parameters", "Z-Controller" and "Mode Properties" section. These sections are an integral part of the Imaging window and represent the most commonly used parameters for the currently selected operating mode. Possible parameters in these sections are described in *Section 10.2: Imaging panel*. Advanced parameters can be accessed via the "More" button in each section, which will open the SPM Parameters dialog on the respective page (see *Section 7.9: SPM Parameters dialog* (page 86)).

At the top, the Imaging window contains a toolbar with commands to control the imaging process: the Imaging toolbar. It is described in *Section 10.3: The Imaging toolbar*.

Apart from the necessary settings, several actions have to be performed before being able to image a sample. These are accessed via the Acquisition tab of the Ribbon, the elements of which are described in detail in *Section 10.4: Acquisition tab*.

Before and during imaging, several panels of the Info pane provide additional information for your reference. The relevant panels are explained in *Section 9.2: Video panel* (page 128) and *Section 9.3: Online panel* (page 135). A description of the other panels is found elsewhere in this manual. Please refer to the *Chapter 15: Quick reference* (page 265) to locate them.

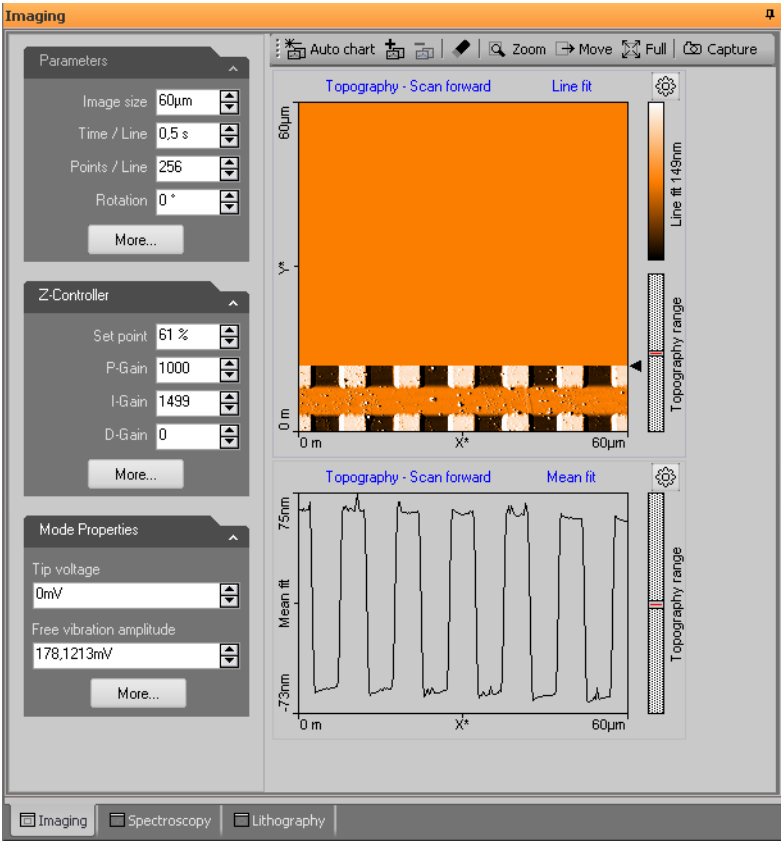


Figure 10-1: The Imaging window

10.2: Imaging panel

The imaging settings use two coordinate systems: the Scanner coordinate system and the Measurement image coordinate system. To separate the two systems, the image axes are denoted by an asterisk (i.e. X*, Y*). The relation between the two coordinate systems is determined by various parameters in the imaging panel. The effect of these parameters is illustrated in *Figure 10-2: Coordinate systems*. In the SPM Control Software, a 'live' schematically illustration is displayed for the active imaging settings in the Scan Position section of the Online panel of the Info pane (see *Section 9.3: Online panel* (page 135)).

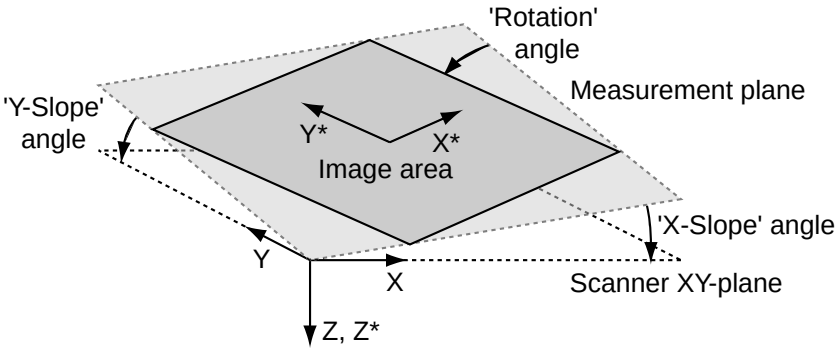


Figure 10-2: Coordinate systems

Imaging Parameter section

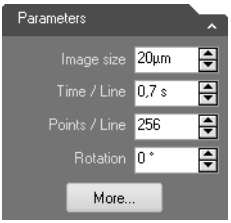


Image size
Defines the image size in both the X* and Y* direction. The size is doubled or halved when the arrows next to the edit box are used.

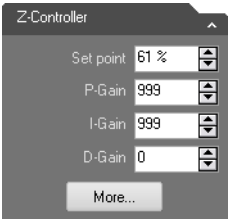
Time / Line
The time needed to acquire a single data line. The time needed for the entire image is displayed in the status bar.

Points / Line
The number of measured data points per line. It also sets the number of lines to the same value.

Rotation
The angle between the X-direction of the scanner and the X* direction of the measurement (Figure 15-2: Coordinate systems).

"More" button
Opens up the SPM Parameters dialog on the "Imaging" page for more advanced parameters (see *Section 10.5.1: Imaging page*).

Z-Controller section



During imaging, the tip–sample interaction is kept constant through the Z-Controller. The Z-Controller is a standard PID controller as is shown in *Figure 10-3: Z-Controller*.

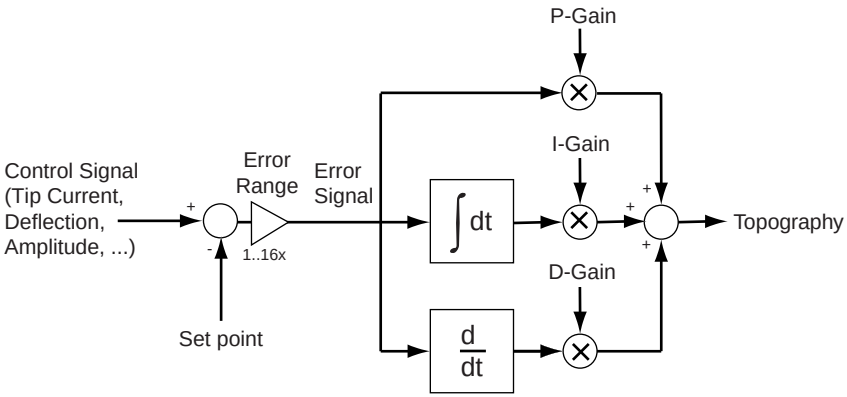


Figure 10-3: Z-Controller

Setpoint
The working point for the Z-Controller. Depending on the operating mode, this is the tunneling current (STM mode), cantilever deflection (static force mode) or relative cantilever vibration amplitude (dynamic force mode). In the later case, the set amplitude is relative to the operating amplitude, set in the Mode Properties Section. For example, when a Setpoint of 70% is used, the Z-Controller will move the tip closer to the sample until the vibration amplitude has decreased to 70% of the vibration amplitude far away from the sample.

P-Gain
The strength of the Z-Controller reaction that is proportional to the error signal. Increasing the P-Gain decreases the error signal.

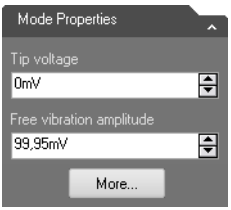
I-Gain
The strength of the Z-Controller reaction that is proportional to the integral of the error signal. Increasing the I-Gain decreases the error signal over time. It is the least sensitive to noise, and usually the dominant contributor to the topography measurement.

D-Gain
The strength of the Z-Controller reaction that is proportional to the derivative of the error signal. Increasing the D-Gain decreases fast changes in the error signal, but also amplifies high frequency noise.

"More" button

Opens the SPM Parameters dialog on the "Z-controller" page for more advanced parameters (see *Section 8.11.2: Z-Controller page* (page 115)).

Mode Properties section



Tip Voltage
This parameter defines the potential to be applied to the tip. The voltage that can be used lies between -10V and +10V.

IMPORTANT

With the STM scan head the sample is automatically connected to the ground of the instrument. With AFM scan heads the sample has to be electrically connected to the instrument's chassis ground for accurate measurements.

Free vibration amplitude
The desired reference amplitude of the cantilever vibration. The cantilever vibrates at this amplitude when it is far away from the sample. The excitation strength is adjusted so that this vibration amplitude is reached.

"More" Button
Opens up the SPM Parameters dialog on the "Operating Mode" page for more advanced parameters (see *Section 8.11.1: Operating Mode page* (page 113).

10.3: The Imaging toolbar

Auto chart
Using this button, the control software displays all meaningful charts for the currently selected operating mode. The actual number of charts varies depending on the mode.

"+" and "–"
With these buttons you can add and remove chart groups, respectively, but not more than minimally makes sense. There will always be a chart group left. Conversely, you can't add more chart groups than the Auto tool would display. You can however still remove or add charts manually (See 13.7 Working with charts)

Clear old chart data
Deletes chart data from a previous measurement. Old chart data can be deleted at all times, regardless of whether a measurement is running or not.

Zoom
Selects an area that is to be measured in more detail. The size and area of the selected zoom area is displayed in the Tool Results panel.

The zoom area is defined by two opposite corners of the area. Pressing the left mouse button at the first corner and holding it down while moving the mouse pointer to the other corner will create a zoom area of user-defined size. Alternatively, an area that has a third of the current measurement size and a center at the current mouse pointer position is defined with a single mouse click at the desired zoom position.

The area defined by the marker can be resized by dragging one of its corners, or moved to a new position by dragging its center point.

To accept the new zoom area:

- Double-click the chart with the left mouse button, or click the "Zoom" button in the Tool Results panel.
  This action modifies the parameters "Image size", "Image offset X" and "Image offset Y" in the Imaging page of the SPM Parameters dialog accordingly (see *Section 10.5.1: Imaging page*).

To abort the zoom function

- Click Zoom again, or use the right mouse button to select "Abort" in the context menu.

Move
The "Move" button moves the position of the imaged area. An interesting corner can thus be moved to the center of the measurement. The Tool Results panel numerically displays the change in position.

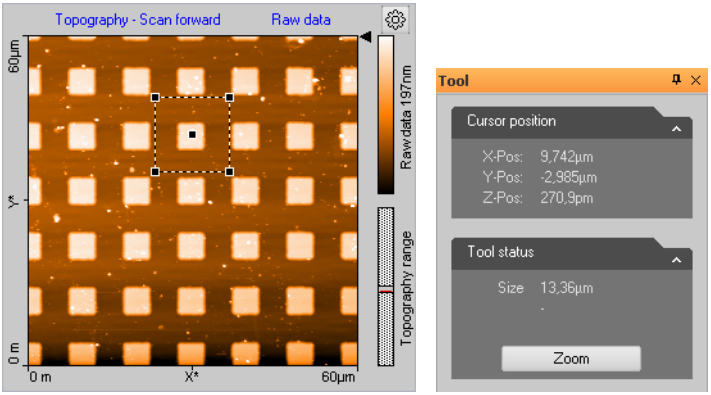


Figure 10-4: Zooming. (Left) The Zoom tool area marker. (Right) The Zoom tool information in the Tool panel of the Info pane.

The change in position is indicated by an arrow. The start of the arrow is defined by the mouse cursor position where the left mouse button is pressed; the end of the arrow by the position where the button is released. With a single click of the left mouse button an arrow ending in the center of the measurement is drawn. The direction of the arrow can be adjusted by dragging its end markers. It can be moved by dragging the center marker.

The image is moved by double clicking, or clicking the "Move" button in the Tool Results panel. To abort the Move function, click the Move-Button again or click the right mouse button and select "Abort" in the context menu.

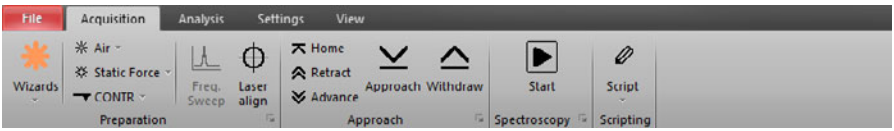
Full

The Full button returns the parameters Scan range to the largest possible values, and "X-Offset" and "Y-Offset" to zero (see *Section 10.5.1: Imaging page*).

Capture

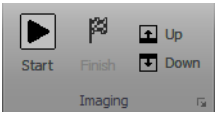
With the "Capture" button, you can immediately copy the current measurement to the History page of the Gallery panel without waiting for the scan to be completed (see also *Section 13.4: Gallery panel* (page 219)). It is stored as a new document and remains open in the Document space of the SPM Control Software.

10.4: Acquisition tab



The Acquisition tab of the Ribbon contains several groups that are important for the imaging of samples. While the Preparation group is explained in *Section 8.2.1: Preparation group* (page 90) and the Approach group is explained in *Section 9.5.1: Approach group* (page 139), the Imaging and Scripting groups are described here.

10.4.1: Imaging group



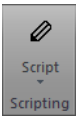
Start
Clicking "Start" starts a measurement and changes the button to "Stop". Clicking "Stop" aborts the measurement as soon as the current scan line is finished.

Finish
Selecting "Finish" will set the "Finish" flag, which will not abort the measurement directly, but will do so when the measurement is finished. Deselecting (i.e., clicking it again) will disable the "Finish" flag so that the measurement will no longer stop automatically when it is finished. The "Finish" button is highlighted when it is flagged.

Up / Down
Starts a single measurement or restarts an ongoing measurement from the selected scanning direction. With the "Up" button the image is scanned from bottom to top. With the "Down" button it is scanned from top to bottom.

Launcher icon
More advanced settings are available through the "Dialog Launcher" icon (at the bottom right corner of the Preparation group), which opens up the SPM Parameters dialog on the Imaging page (see *Section 10.5.1: Imaging page*).

10.4.2: Scripting group



The Scripting Interface is an optional component for creating user defined scripts (software components) to add new features or automating tasks. For details, see "Help Panel" >> "Manuals" >> "Script Programmer's Manual".

Important:

The Scripting Interface is a purchase option and has to be activated using the Access Codes page (see *Access Code* (page 249) of the Options dialog.

The "Script" button

This button opens the Script Editor Dialog. In this Dialog, a script source code can be Loaded, Edited, Saved and Run directly.

The "Script" button drop-down menu

Accessed by clicking the arrow head at the bottom part of the "Script" button. In this drop-down list, scripts from the standard scripting directory are displayed and can be started by selecting the corresponding menu item. The menu item's name is equal to the script's name without the script extension (*.vbs) and is sorted alphabetically. The standard directory is configured through the Scripting Acquisition and Analysis file paths (accessed via "File" >> "Options" >> "Scripting" (see *Scripting* (page 246)).

At the bottom of the drop-down menu, the "Run from File…" menu item is displayed. It allows selection and execution of a script file anywhere on your harddisk (or other storage media). With the selection of this menu item, a File Open dialog is displayed and a script file can be manually selected. This script file is executed directly after "Open" is selected.

10.5: SPM Parameters dialog

10.5.1: Imaging page

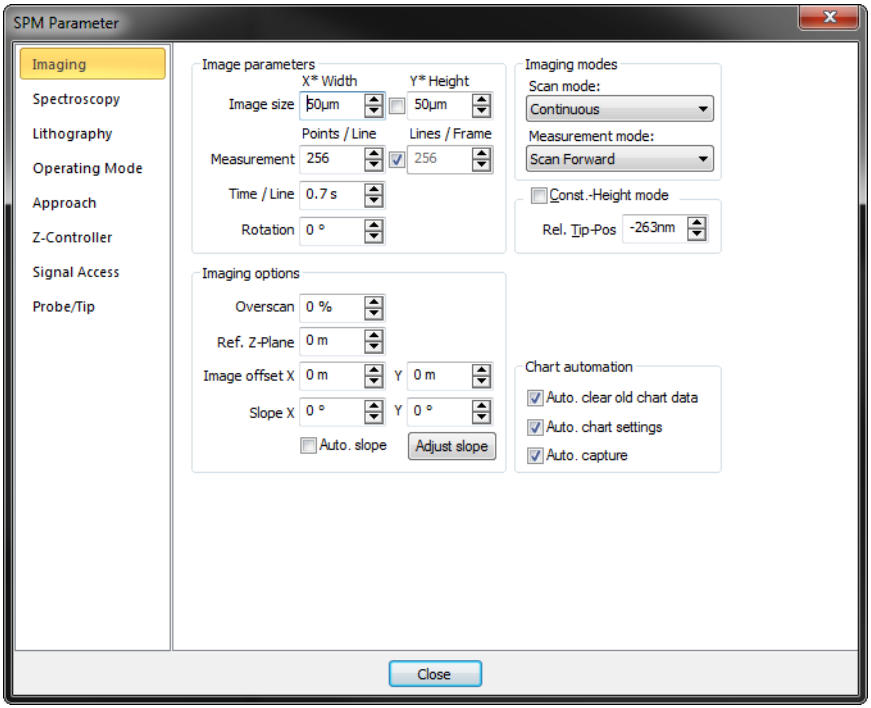


Image parameter

Image size
The image size in X*-direction and the image size in Y*-direction. When the Check-box is active, the image Height is always identical to the Image width.

Measurements
The number of measured data points and data lines in an image. When the Check-box is active, the number of Lines is always equal to the number of Points / Line.

Time / Line
The time needed to acquire a data line. The time needed for the entire image is displayed in the status bar.

Rotation
The angle between the X-direction of the scanner and the X* direction of the measurement (Figure 15-2: Coordinate systems).

Imaging options

Overscan
The "Overscan" determines how much the effective scan range is increased relative to the image width. This will eliminate edge effects caused by the reversal of the scanning motion by not recording or displaying them in the measurement image. Disadvantages of using Overscan are that the maximum scan range is reduced, the tip moves slightly faster over the sample with the same "Time/Line" setting, and the tip may hit large features outside the measured image.

Ref. Z-Plane
The height of the reference plane. This height reference is used when the Z-Controller output is cleared, and when the Z-position is not modulated relative to the current surface position during spectroscopy measurements.

The reference plane for the image can be aligned to the surface of the sample using the slope parameters (see *Figure 5-2: Sample and measurement orientation before slope adjustment* (page 64) or *Figure 10-2: Coordinate systems* (page 152)).

Image offset X/Y
The center position of the measured area.

Slope X
A positive value rotates the image plane around the Y-axis counterclockwise.

Slope Y
A positive value rotates the image plane around the X-axis counterclockwise.

The center position of the measured area can be changed by typing its position as well as by using the Move tool in the Imaging toolbar. The zero position corresponds to the center position of the scanner.

Adjust slope
The "Adjust slope" button will cause the control software to set appropriate values for X- and Y-slope by performing two single line scans (one in X- and one in Y-direction) and determining the respective slopes via line fitting, thus electronically compensating for these measurement plane slopes (see *Section 5.2: Adjusting the measurement plane* (page 63) for details).

Auto slope
Automatically performs the same action as the "Adjust slope" button does. It adjusts the slopes with each new "Start" of imaging.

Imaging modes

Scan mode
This parameter defines how the images are acquired and displayed:

– **Continuous**
  The acquisition direction is reversed after each scan: from bottom to top and vice versa.
– **Cont.Up**
  The acquisition direction is always from bottom to top.
– **Cont.Down**
  The acquisition direction is always from top to bottom.

Measurement mode
This parameter defines how each imaging line is acquired and stored:

– **Forward**
  During forward scan only (left to right in the image).
– **Backward**
  During backward scan only (right to left in the image).
– **Forw.&Backw.**
  During both forward and backward scan.

Const. Height mode

When the Constant Height imaging mode is enabled, the Z-Controller is turned off during the scan (as a consequence, the Probe Status light will blink green). Instead, the scanner scans along a straight line, that should be parallel to the surface. The slope of the line is defined by the X- and Y-Slope parameters. These parameters should be set as described in *Section 5.2: Adjusting the measurement plane* (page 63). The height of the line is determined at the start of each scan line: First the Z-Controller is turned on. Once the tip position is stable, the Z-Controller is turned off and the tip is moved away from the sample by the distance set by the parameter Rel. Tip-Pos.

The Constant Height Imaging mode is mainly useful for EFM and MFM measurements. For more information on how to do Magnetic Force Microscopy, refer to technical note "TN00031 — Operating Nanosurf AFMs in MFM mode" which can be found in the "Technote" section of the Help panel.

Rel. Tip-Pos
This parameter defines the distance by which the Tip is moved towards the sample from the position that corresponds to the Setpoint. A negative setting will move the tip away from the sample.

Chart automation

Auto clear old chart data
Automatically clear the chart data from a measurement when a measurement is restarted (either when a scan is restarted manually, or when a previous scan has finished and measurement recommences as determined by the scan mode (see *Scan mode* (page 161).

Auto chart settings
If checked, the chart arrangement is automatically updated (see also *Auto chart* (page 155)).

Auto Capture
If checked, all measurements are automatically stored in the history Gallery. If unchecked, you have to click the "Capture" button in the Imaging tool bar to manually save your measurement data.

CHAPTER 11:

Spectroscopy

11.1: Introduction

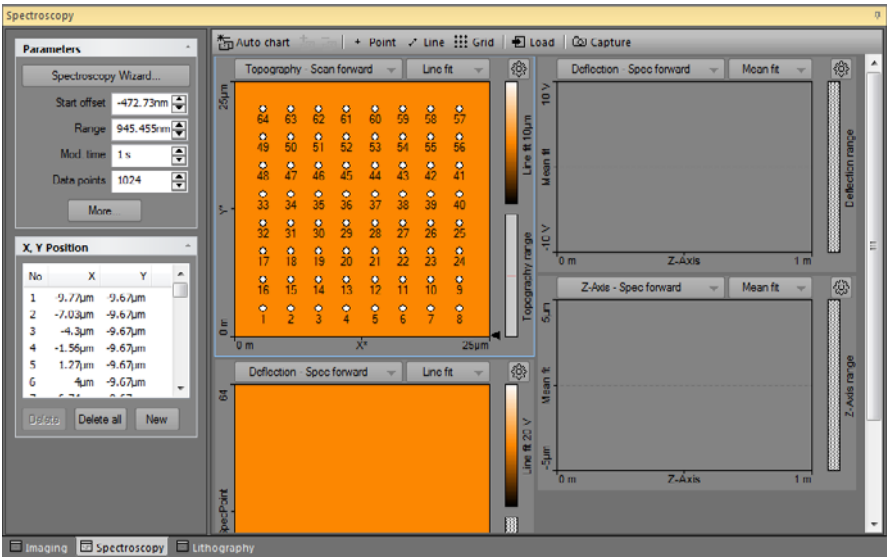


Figure 11-1: Spectroscopy window

Spectroscopic measurements are performed in the Spectroscopy window, which is opened by clicking the Spectroscopy tab in the Measurement pane. The Spectroscopy window contains the Spectroscopy toolbar, with commands that control the spectroscopy processes, and the Spectroscopy panel (parameter area), with parameters that determine how the spectroscopy measurement is performed.

The Spectroscopy window also contains a number of charts that display the data from a previous imaging measurement and the data from the ongoing spectroscopic measurement. The Spectroscopy window can display as many charts as the size of the window can accommodate. It is recommended to display at least two charts, one Color map of a previous Topography measurement of the area where the spectroscopy measurement is performed, and one Line graph of the current spectroscopy measurement. For more information on adding and changing charts see *Section 13.3: Charts* (page 209).

In general, a spectroscopic measurement is a measurement of an input signal as a function of a modulated output. Common spectroscopic measurement types are:

- Force–Distance curves in AFM Static, Spreading Resistance, and Lateral Force operating modes
- Amplitude–Distance or Phase–Distance curves in AFM Dynamic operating modes

- Tip Current–Distance curves for STM operating mode
- Tip Current– Tip Voltage curves in AFM and STM operating modes

Tip

Use the Spectroscopy wizard (“Wizards” >> ”Spectroscopy...”) to quickly prepare spectroscopy parameters. The wizard can prepare appropriate parameters for all common spectroscopy modes.

The XY-Position section of the Spectroscopy panel stores a list of points where such measurements are to be performed. To define these positions, the “Point”, “Line” or “Grid” tools in the Spectroscopy toolbar help you to define these positions graphically by using the mouse. Alternatively, individual positions can also be defined manually by entering their X and Y coordinates in the XY-Position dialog, opened by clicking the “New” button in the XY-Position section (also see *New* (page 178)). The positions in the list are also shown as numbered circles in the color map chart of the surface (see *Figure 11-2: Example of a multiple position measurement using the Grid tool*).

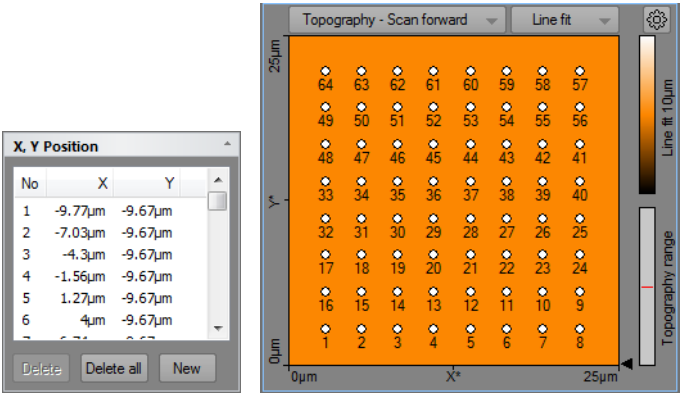
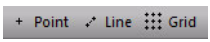


Figure 11-2: Example of a multiple position measurement using the Grid tool. ((Left) List of coordinates. (Right) Measurement positions as shown on the sample surface.

IMPORTANT

In the spectroscopy toolbar, the SPM control software has three graphical tools to define positions using the mouse. Use these graphical tools to easily define X/Y-positions:



(also see *Section 11.4: Spectroscopy toolbar* (page 178))

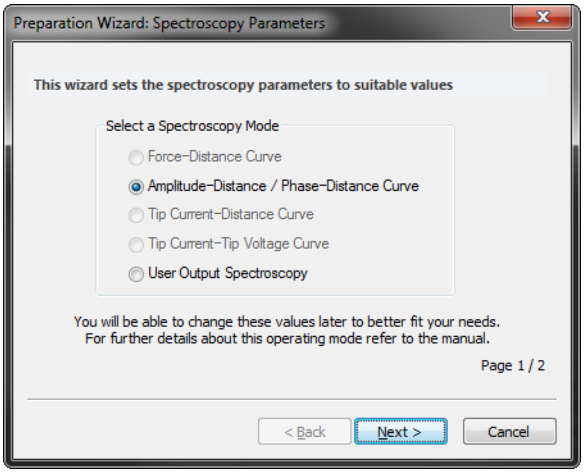
Individual points created using any method can be easily repositioned by dragging the respective circle to its new position in the Topography overview chart.

In general, there are two types of modulation methods:

– **"Fixed length" modulation**
  This type of modulation has a fixed start and end value. It is freely available with the Standard spectroscopy level (see *Section 11.6.2: Spectroscopy page (standard level)*).
– **"Stop by value" modulation**
  This type of modulation has a fixed speed from a start value until a certain measurement value is reached. This type of spectroscopy is only available with the Advanced spectroscopy level (see *Section 11.6.3: Spectroscopy page (advanced level)*).

11.2: Spectroscopy Wizard

The Spectroscopy Wizard helps you to setup the spectroscopy parameters for a spectroscopy experiment:



The wizard will set all spectroscopy parameters, modes and settings to reasonable values, so that the desired spectroscopy function is well prepared for almost all cases. The wizard takes overall system settings (e.g Cantilever type, Z- Feedback Setpoint, Free Vibration Amplitude, etc.) into account when it calculates the parameters it proposes as default values.

The Spectroscopy wizard takes you through a two-step process:

1. Select the spectroscopy mode you wish to perform.
2. Accept or change the proposed parameters.

After clicking the "Finish" button, the Wizard sets all spectroscopy parameters. These can be viewed in the Spectroscopy page of the SPM Parameters dialog (see *Section 11.6.1: Spectroscopy page*) and may be adjusted at any time to better fit your needs.

If already approached to the surface, you are ready to start the Spectroscopy by clicking the "Start" button in the Spectroscopy group of the Acquisition ribbon (see *Section 11.5.1: Spectroscopy group*). If no X/Y-Position is defined, spectroscopy will be performed in the center of the image, respecting the selected XY-offset in the imaging parameters.

IMPORTANT

- A disabled spectroscopy mode means that this mode is not available for the currently selected operating mode. "Amplitude–Distance curve", for example, is only possible in "Dynamic Force" or "Phase Contrast" operating modes and not in "Static Force" operating mode.
- A disabled parameter means that it is only available if the Advanced Spectroscopy Level is activated by a correct Access code (see *Access Code* (page 249)).

11.2.1: Force–Distance

The Force–Distance curve is a spectroscopy mode where the cantilever is moved while the deflection signal is measured. With Force–Distance spectroscopy, the typical snap-in and release effect of the tip–sample interaction can be measured. Additionally, the cantilever spring constant and the system's deflection sensitivity can be precisely calibrated (see *Section 14.8.2: Probe/Tip page* (page 262)).

A "fixed length" modulation can be safely performed with the Standard Spectroscopy level when the tip starts at the surface (and the Z-position of the surface is therefore already known) and is subsequently moved away to a retracted position and then back again.

A "stop by value" modulation can only be performed with the Advanced Spectroscopy level since only there the it is possible to enter an appropriate stop value. Here it is also possible to start from a retracted position and then move towards the surface until a given Stop criterion is reached and to retract again afterwards.

A "fixed length" Force–Distance spectroscopy experiment is typically divided into 4 distinct phases (see *Figure 11-3*, Left):

1. Tip is approached (i.e. in contact with the surface).
2. Move the tip to a defined position (Range) above the surface while measuring the deflection signal (and any other input signals that the current measurement mode may allow). This is called the "Forward Modulation phase".

3. Move the tip back to the surface while measuring deflection (and any other input signals). This is the "Backward Modulation phase". Its duration is the same as during the forward phase. The direction is opposite to that of the forward phase.
4. Remain approached (keep Z-controller active). If more spectroscopy measurements are to be performed, move to the next measurement (XY) position (also with active Z-feedback).

A "stop by value" Force–Distance spectroscopy experiment is typically divided into 8 distinct phases (see *Figure 11-3*, Right):

1. Start from a (fully) retracted Z-position.
2. Move the tip to a defined position above the surface (start offset).
3. Move the tip toward the surface and measure the deflection signal (and any other input signals that the current measurement mode may allow). This is called the "Forward Modulation phase".
4. Stop at a defined deflection value (Fwd Stop value) and maintain this Z-position for a certain amount of time. This is called the "Fwd pause phase". During the pause phase, data is still being recorded, but may have a different sample rate.
5. Move the tip away from the sample to a defined position while measuring deflection (and/or other input signals). This is the "Backward Modulation phase".
6. Stop at a defined deflection value (Bwd Stop value) and maintain this position for a certain amount of time, again while recording data. This is the "Bwd pause phase".
7. Change the modulation signal back to its initial value.
8. If more spectroscopy measurements are to be performed, move to the next measurement (XY) position.

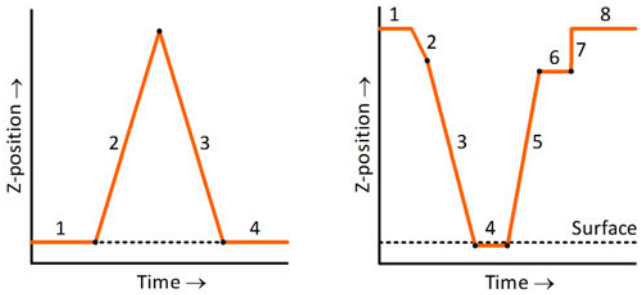
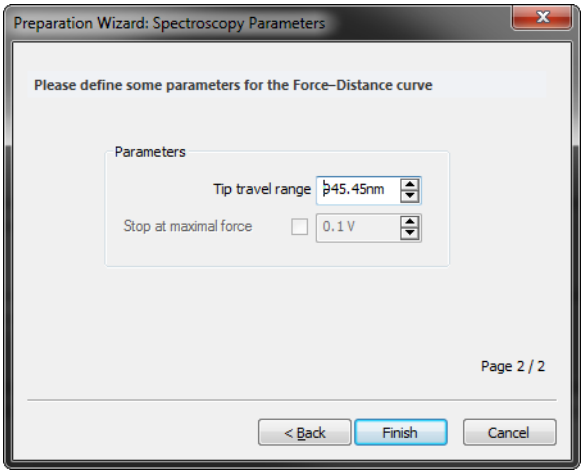


Figure 11-3: Typical phases of Force–Distance curves. (Left) Fixed length (standard) modulation. (Right) Stop by value (advanced) modulation.

IMPORTANT

- Force–Distance Curve is available in all Static force operating modes.
- Cantilevers with low spring constants are typically used.



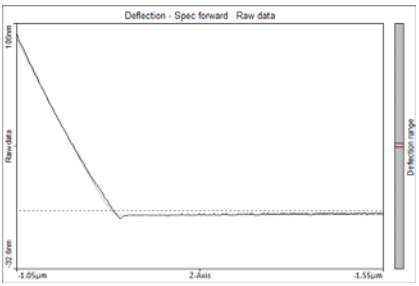
Parameters

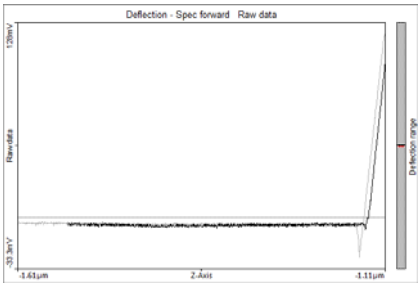
Tip travel range
Defines the range of the desired tip movement toward/away from the sample during measurement. In fixed length modulation, this parameter sets the actual forward and backward travel ranges. In stop by value modulation, this parameter sets the maximum travel ranges (if not shortened by the respective stop values).

Stop value
If checked, the forward spectroscopy stops its forward movement as soon as the defined deflection value is reached. This parameter is only available when advanced spectroscopy has been activated via the proper access key.

Results

Typical measurement results will look as follows (Left: fixed length; Right: stop by value):





Usage

Force–Distance curves can be easily analyzed in the Nanosurf SPM control software to reveal the system's deflection sensitivity (see below). These can then be entered into the respective fields on the Probe/Tip page of the SPM Parameters dialog (see *Section 14.8.2: Probe/Tip page* (page 262)) and allow the software to correctly express measurement data (voltage) as height information (e.g. in nm). If the cantilever spring constant has been determined and entered in the corresponding field on the Probe/Tip page as well, the software can also accurately express measurement data as Force (in Newton).

To perform a calibration:

1. Record a Force—Distance curve as described above.
2. Use the Measure Length tool (see *Measure Length* (page 225)) on the Ribbon's Analysis and draw a line on the descending or ascending part of the force curve (see *Figure 11-4: Deflection sensitivity calibration*, Left).
3. From the numbers shown in the Tool status area of the Tool panel of the Info pane (*Figure 11-4: Deflection sensitivity calibration*, Top right), divide Height by Width to obtain the slope in V/m. In the example shown in *Figure 11-4*, the slope calculates to 303 mV / 127.9 nm = 2369038 V/m.
4. To obtain the Deflection sensitivity, divide 10 V (the scale of the AFM detector) by the slope. In the example shown in *Figure 11-4*, this corresponds to 4.221×10^{-6} m.
5. Enter this number in the Detector Sensitivity field of the Probe/Tip page of the SPM Parameters dialog. In the example shown, 4.221 µm has to be entered (see *Figure 11-4: Deflection sensitivity calibration*, Bottom right).

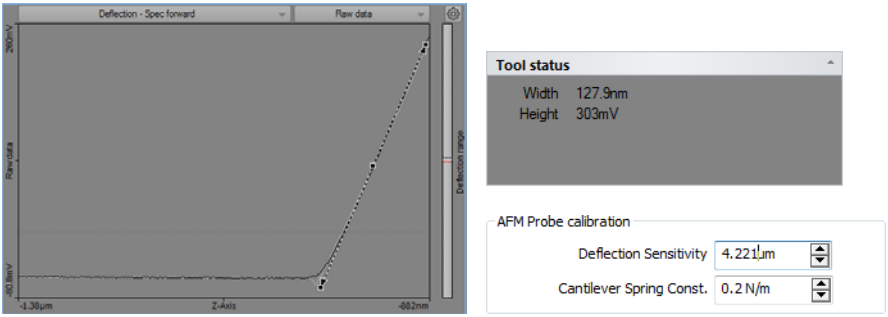
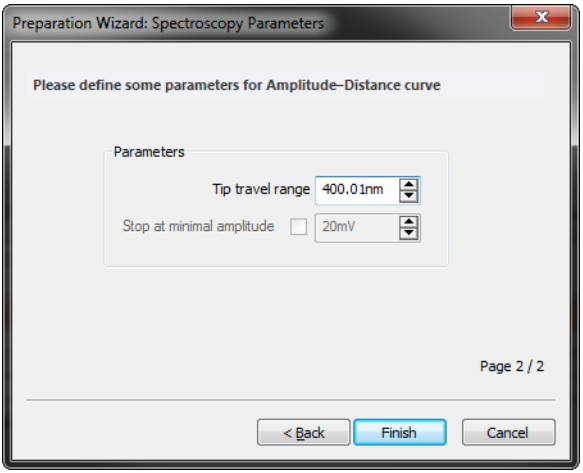


Figure 11-4: Deflection sensitivity calibration.

11.2.2: Amplitude–Distance / Phase–Distance

The Amplitude–Distance / Phase Distance curve is a spectroscopy mode where the cantilever is moved while the amplitude or phase signal is being recorded. With this modulation, the typical amplitude reduction or phase shift effect due to the increasing tip–sample interaction can be measured (see *Results* (page 172)). Note that while both amplitude and phase signal can be recorded simultaneously, only the amplitude signal can be used as Stop value in Advanced Spectroscopy mode.



IMPORTANT

- Amplitude–Distance / Phase–Distance Curve is only available in “Dynamic Force” or “Phase Contrast” operating mode.
- Cantilevers with high spring constants are typically used.

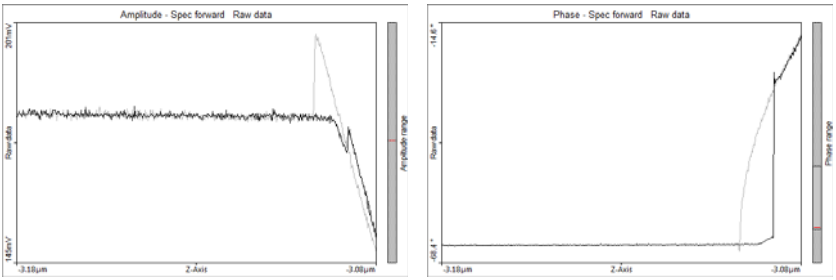
Parameters

Tip travel range
Defines the range of the tip movement.during the forward and backward phases of the spectroscopy measurement.

Stop value
If checked, the forward spectroscopy stops its forward movement as soon as a defined reduced amplitude value is reached. This parameter is only available when advanced spectroscopy has been activated via the proper access key.

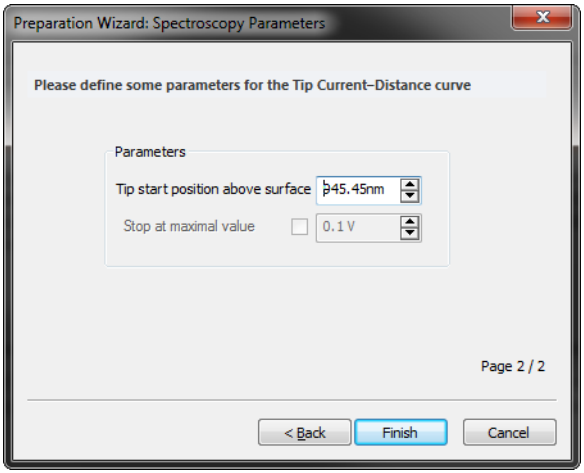
Results

Typical measurement results will look as follows (Left: Amplitude; Right: Phase):



11.2.3: Tip current–Distance

The Tip current–Distance curve is a spectroscopy mode where tip current is measured while the tip is moved. In STM mode, this modulation is typical used to show that the tip current is exponentially increasing when approaching the sample surface.



Info:

- The Tip current–Distance curve is only available in STM mode and in the AFM "Spreading Resistance" operating mode.
- AFM users must electrically connect the sample to the ground connector on the scan head to apply a tip–sample voltage difference.

Parameters

Tip travel range
Defines the range of the desired tip movement toward the sample during the forward measurement phase.

Stop value
If checked, the forward spectroscopy stops its forward movement as soon as a defined value is reached. In STM mode, the stop value corresponds to a defined tip tunneling current. In AFM Spreading Resistance mode, the stop value does not correspond to a tip current, but (as with Force–Distance measurements) corresponds to a defined deflection signal. The tip current is measured as a separate channel in Spreading Resistance mode.

11.2.4: Tip current–Tip voltage

The Tip current–Tip voltage curve is a spectroscopy mode where the tip is not moved, but where the tip voltage is changed instead. During this voltage change, the tip current signal is measured.

A Tip current–Tip voltage spectroscopy experiment is typically divided into 5 distinct phases (see *Figure 11-3*, Left):

1. Tip voltage is at a resting potential (e.g. 0 V).
2. Tip voltage is set to a positive value (e.g. +5 V).
3. Tip voltage is slowly set to a negative voltage (e.g. –5 V) while the Tip current is being measured.
4. Tip voltage is returned to its resting potential.
5. Tip voltage remains at this potential. If more spectroscopy measurements are to be performed, move to the next measurement (XY) position.

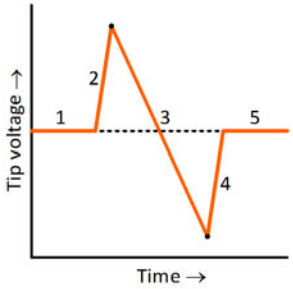
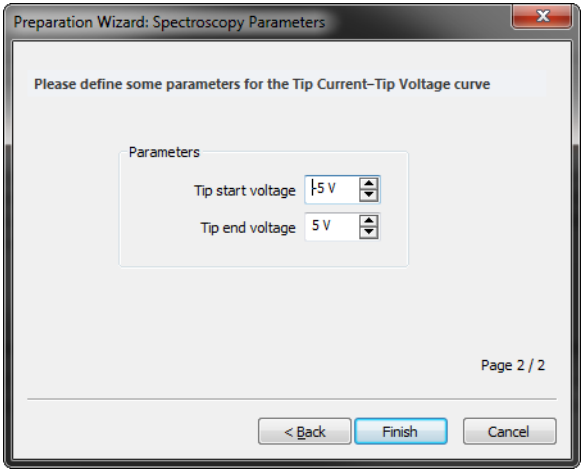


Figure 11-5: Typical Tip Current–Tip Voltage curve. Dotted line represents resting potential.

Info:

- The Tip current–Tip voltage curve is only available in STM mode and in the AFM "Spreading Resistance" operating mode.
- AFM users must electrically connect the sample to the ground connector on the scan head to apply a tip–sample voltage difference.



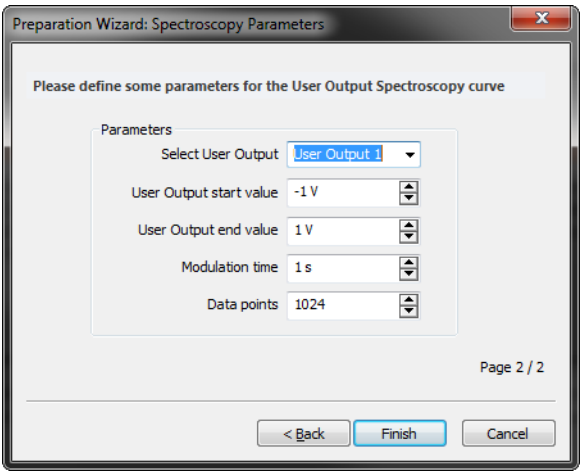
Parameters

Tip start voltage
Defines the start point of the voltage scan.

Tip end voltage
Defines the end point of the voltage scan.

11.2.5: User Output Spectroscopy

The User Output spectroscopy mode can be used to do spectroscopic measurements with external sources controlled by the User outputs of the Signal Module A. During spectroscopy, the currently active signals (defined by the selected operating mode) are measured.



Parameters

Selected User Output
The User Output signal to use for modulation.

User Output start value
Defines the start point of the modulation.

User Output end value
Defines the end point of the modulation.

Modulation time
The time during which the modulation takes place.

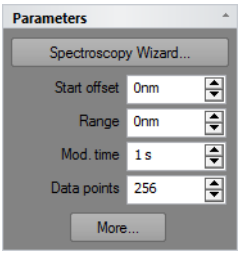
Data point
The number of data points to record during modulation.

Info:

User output spectroscopy is only available if Signal Module A is present in your system.

11.3: Spectroscopy panel

Parameters section



Spectroscopy Wizard
This button starts the Spectroscopy wizard (see *Section 11.2: Spectroscopy Wizard* (page 166) for details).

Start offset
The starting point for the spectroscopy modulation

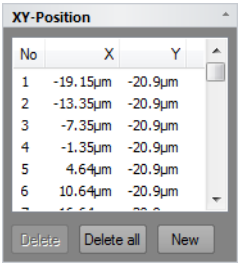
Range
The range over which the Modulated output is changed. The "Spec Forward" data is measured from the "Start offset" value until "Start offset" + "Range". "Spec backward" data is measured in the opposite direction. The "Spec forward" data is always measured before the "Spec backward" data. For spectroscopy as a function of distance (Z-axis modulation), more negative values are further away from the sample whereas more positive values go towards (or even into) the sample.

Mod. time
The time used to change the Modulated output from its the start to end value.

Data points
The number of data points measured while the Modulation output is changed. The data points are equally distributed over the modulation range.

"More" button
Opens up the SPM Parameters dialog on the Spectroscopy page for more advanced parameter settings (see *Section 11.6.1: Spectroscopy page* (page 180)).

XY-Position section



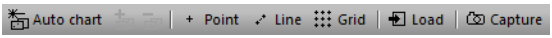
The Position section lists the positions to be used for spectroscopy measurements. The list can be populated using tools from the Spectroscopy toolbar or by adding individual positions using the "New" button (see below). Any position on this list can be moved to a new location by using the mouse to drag the corresponding circle in the overview chart.

Delete
Removes the currently selected measurement position from the list.

Delete all
Removes all measurement positions from the list.

New
Opens up a dialog to add a new XY-coordinate for Spectroscopy measurement.

11.4: Spectroscopy toolbar



Auto chart
Using this button, the control software displays all meaningful charts for the currently selected operating mode. The actual number of charts varies depending on the mode.

"+" and "–"
With these buttons you can add or remove chart groups, respectively, but not more than what minimally makes sense. There will always be a chart group left. Conversely, you can't add more chart groups than the Auto tool would display. You can however still remove or add charts manually (See *Section 13.3.1: Working with multiple charts* (page 211)).

Point
Activates the single point spectroscopy mode. It defines the position of the spectroscopy measurement by mouse. Click in the topography Color Map chart at the position where the spectroscopy measurement should take place. A small white circle appears at this position. The positions coordinate is transferred to list in the XY-Position section.

Line
Activates the line spectroscopy mode. Defines the start and end position of the spectroscopy measurement by mouse. Click and hold the left mouse button in the topography Color Map chart at the position where the spectroscopy measurement should start. Move the mouse to the end position and release the left mouse button. A line with measurement positions is overlaid on the Color map. The position coordinates are transferred to the XY-Position section of the Spectroscopy panel.

Grid
Activates the grid spectroscopy mode. Defines opposite corners of a rectangular grid of spectroscopy measurements by mouse. Click and hold the left mouse button down while dragging from one corner of the grid to the opposite corner. Releasing the mouse button will overlay the grid's measurement positions on the topography view.

Load
Fills the Topography Color Map chart in the Spectroscopy window with the current measurement of the Imaging window. Selection of "point", "line", or "grid" measurement positions can be performed in this chart.

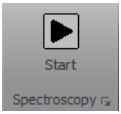
Capture

A click on "Capture" saves the current spectroscopy measurement data to the History page of the Gallery panel, even when the measurement(s) have not been completed yet. The spectroscopy data are stored as a new document and remain open in the Document space of the SPM software.

11.5: Acquisition tab

During spectroscopy, all groups of the Acquisition tab are identical to those during imaging of the sample, with exception of the Imaging group, which is replaced by the Spectroscopy group.

11.5.1: Spectroscopy group



Start
Clicking "Start" starts a spectroscopy measurement sequence and changes the button to "Stop" until the measurement sequence is finished. Clicking "Stop" aborts the measurement sequence as soon as the current modulation period is finished.

Launcher icon
More advanced settings are available through the "Dialog Launcher" icon (at the bottom right corner of the Spectroscopy group), which opens up the SPM Parameters dialog on the Spectroscopy page (see *Section 11.6.1: Spectroscopy page*.

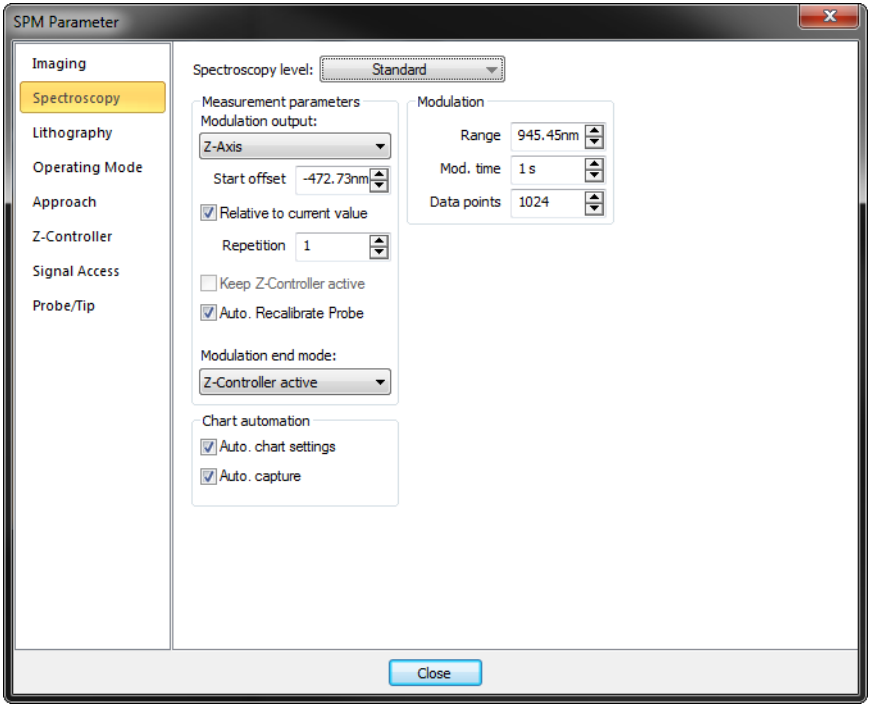
11.6: SPM Parameters dialog

11.6.1: Spectroscopy page

The Spectroscopy page of the SPM parameter dialog contains all parameters relevant for performing spectroscopy measurements. Two levels of parameter complexity are distinguished and can be selected at the top of the Spectroscopy page:

- **Standard Spectroscopy**
  In this level, Spectroscopy works in fixed-length modulation mode and without pause phases. Forward and Backward phases will always have the same absolute range. This mode serves the most common spectroscopy needs and is easy to operate. For details see *Section 11.6.2: Spectroscopy page (standard level)*.
- **Advanced Spectroscopy**
  In this level, the "Stop by value" modulation modes is also supported and many more parameters for each phase are available. For details see *Section 11.6.3: Spectroscopy page (advanced level)*. This level is only available when it has been unlocked with a valid access key (see *Access Code* (page 249).

11.6.2: Spectroscopy page (standard level)



Measurement parameters group

Modulation Output

This parameter defines the output signal used to drive the spectroscopy (horizontal axis in the resulting spectroscopy graph). All possible signals (vertical axis in the spectroscopy graph) are recorded while this modulation output signal is changing its value from Start ("Start offset") to End ("Start offset" + "Range"). The number of available modulated outputs depends on the scan head and the number of installed modules. Possible values are: "Z-Axis", "Tip Potential" and the names of the User Outputs.

IMPORTANT

In Z-Axis modulation mode, positive values mean closer/into to the surface, while negative values are away from the surface.

Start Offset
Defines the absolute or relative start value of the modulated output signal during a new modulation.

Relative to current value
If checked, the start offset value is used as a value relative to the current value. If unchecked the Start Offset is used as an absolute value for the start of a new modulation. In case of Z-Axis modulation, the last known surface position is used as reference point. This means that if the tip was at some point retracted after approach, it still uses the Z-height at which contact was established.

Repetition
This value defines the number of times a modulation measurement is repeated at each XY-Position. Each measurement is stored individually.

Keep Z Controller active
When checked, the Z-Controller will continue to change the Z-position to keep the tip–sample interaction constant. This option is not available when the Modulated output is set to Z-Axis. This setting can for example be used to measure Tip current as a function of applied voltage while keeping the tip–sample force constant. If unchecked, the Z-Axis is kept at its last value prior to the start of the modulation.

Auto readjust probe
If checked, the offset of the probe signal is readjusted prior to each modulation. With this readjustment, changes of the probe's properties over time (e.g. temperature-induced drift) can be compensated.

Modulation End Mode
While moving from one X/Y-Position to the next, this parameter defines the tip's Z-Axis behavior. "Keep last Z-Pos" deactivates Z-feedback while moving and keeps the Z-Axis at the last Z-height. This selection is recommended for positive Range values (in particular during Advanced spectroscopy). "Z-Controller active" activates the feedback during the movement; the surface is tracked. This selection is recommended for negative Range values.

Modulation

Range
This value defines the range over which the output value is changed during the forward modulation phase, starting from Start Offset. The range can be positive or negative (also see *IMPORTANT* (page 181)). The backward modulation automatically follows the reverse direction range. After both (fwd/bwd) modulation phases, the modulation output will be at the Start offset value again.

Mod. time
This value defines the time used to move over the range set by the Range parameter during both modulation phases.

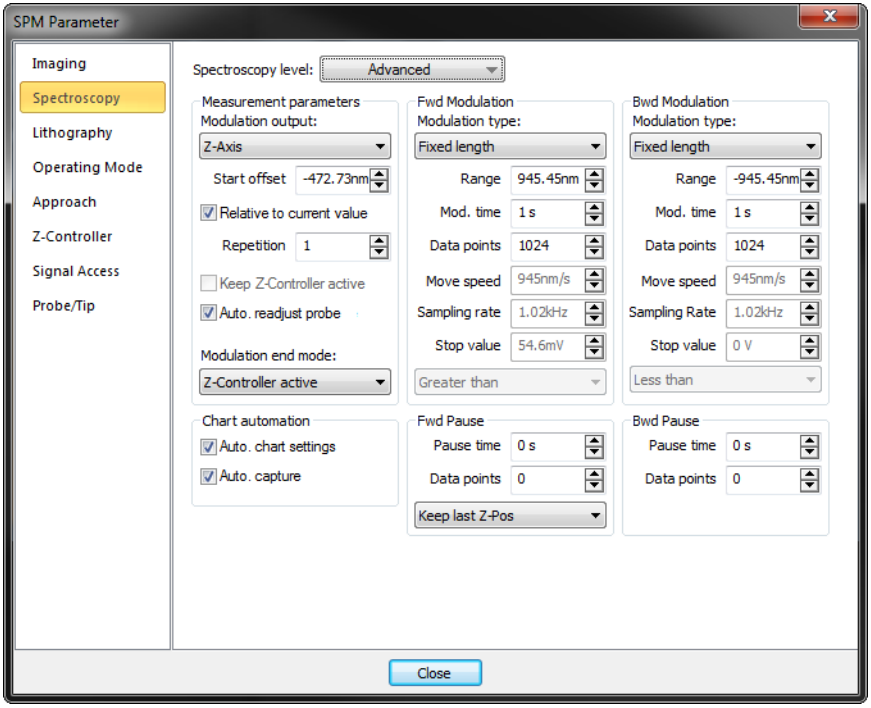
Data points
This value defines the number of data points that will be measured during each modulation phase. The data points are equally distributed over the complete modulation range.

Chart automation

Auto chart settings
If checked, the chart arrangement is automatically updated (see also *Auto chart* (page 178)).

Auto Capture
If checked, all spectroscopy measurements are automatically stored in the history Gallery. If unchecked, you have to click the "Capture" button in the Spectroscopy tool bar to manually save your measurement data.

11.6.3: Spectroscopy page (advanced level)



The advanced level of the Spectroscopy page of the SPM Parameters dialog provides much more control over Spectroscopy experiments than the standard level. In addition to the parameters described in *Section 11.6.2: Spectroscopy page (standard level)*, the advanced level Spectroscopy page contains the following elements:

Fwd Modulation / Bwd Modulation

Modulation Type

In "Fixed Length" the modulation phase is exactly defined by Range, Mod. Time and Data points. All measurements (repetitions, different positions) will have the same length. In "Stop by value" this is not the case; only maximum values are given. Since the input channel used for feedback during imaging (e.g. deflection or amplitude) is used to stop each modulation phase at a preset point (see *Stop Value* (page 185)), the lengths of each modulation phase (for each repetition, different position) will most likely be different.

Range
In "Fixed length" modulation, this value defines the change of the output value during the modulation phase. For forward modulation it starts from Start offset. The range can be positive or negative (also see *IMPORTANT* (page 181)). For the backward modulation it starts from the last value of the forward pause phase and with its own Range settings. Therefore, the modulation output value at the end of the backward modulation phase can be different from the start value of the forward phase. In "Stop by value" modulation, this field shows a maximum value, calculated from the Data points, Move speed, and Sampling rate parameters (see below).

Mod. time
In "Fixed length" modulation, this value defines the time used to move over the modulation range during the respective modulation phase. In "Stop by value" modulation, this field shows a maximum value, calculated from the Data points and Sampling rate parameters (see below).

Data points
This value defines how many data points will be measured during the respective modulation phase. Data points will be equally distributed over the entire modulation range. In "Fixed length" modulation, the number of data points are exactly defined by this value. In "Stop by value" modulation, this is the maximum is number of datapoints that will be recorded.

Move speed
In "Stop by value" modulation, this value defines the speed at which the modulation output is changed. The move speed can be positive or negative (also see *IMPORTANT* (page 181)). For the backward modulation it can have a different value than for the forward modulation. Therefore the modulation output value at the end of the backward modulation phase can be different from the start value (Start offset). In "Fixed length" modulation mode, this value is calculated from the Range and Mod. time parameters (see above).

Sampling rate
In "Stop by value" modulation, this value (in Hz) defines the number of data points measured per second during the respective modulation phase. In "Fixed length" modulation, this value is calculated form the Data points and Mod. time parameters.

Stop Value
In "Stop by value" modulation, this value defines the abort criterion that has to be reached in order to stop the respective modulation phase. The signal which is monitored is the Z-controller input signal (e.g. deflection or amplitude) and depends on the selected Operating mode. The value may be positive or negative. In "Fixed length" modulation mode the value shown here has no meaning.

Stop Mode
If "Greater than" is selected the modulation is stopped if the measured value is more positive than "Stop value". If "Less than" is selected the measured value has to be more negative. For Z-Axis modulations, "Greater than" should be selected for Static operating modes and "Less than" for Dynamic operating modes.

Fwd Pause / Bwd Pause

Pause time
This value defines the waiting time after the respective modulation phase before the next phase is initiated.

Data Points
This value defines the number of data points that will be recorded during the respective pause phase. The number of data point recorded during a pause phase can be different from the number of data points recorded during the respective modulation phase. If set to zero, the respective Pause time will be automatically set to zero as well (and vice-versa).

Z-Axis Pause Mode
In "Z-Axis Modulation" Mode (see *Modulation Output* (page 181)), it is possible to select the Pause-Phase behavior via this selector. With "Keep last Z-Pos" it maintains the final value of the modulation phase. With "Z-Controller active" it activates Z-controller feedback during the pause; the surface is tracked.

CHAPTER 12:

Lithography

12.1: Introduction

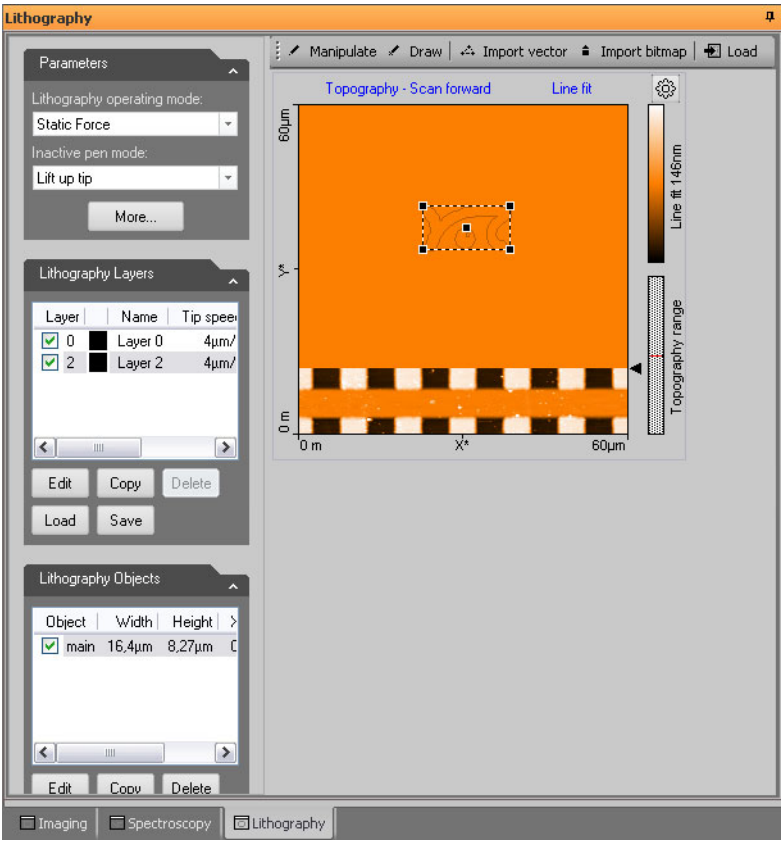


Figure 12-6: Lithography window

In the context of Scanning Probe Microscopy (SPM), Lithography is the process of modifying a sample surface with the goal of creating a pattern on that surface with the SPM tip. In the Nanosurf SPM software, this is accomplished in the Lithography window. The Lithography window is opened by clicking the Lithography tab in the Measurement pane.

The Lithography window contains the Lithography toolbar, with commands that control lithography-related processes, and the Lithography panel, with parameters that determine how the Lithography is performed.

By default, the Lithography window also contains the Lithography Preview display (see *Section 12.6: Lithography preview* (page 204)) and a Color map chart of the current Topography measurement. The Lithography window can however display more charts, should this be desirable. For more information on adding and changing charts, see *Section 13.3.1: Working with multiple charts* (page 211).

IMPORTANT

Lithography of objects drawn by hand and direct manipulation of the tip is available as standard. Issuing of lithography commands through the Scripting Interface requires a license for the Scripting Interface. Import of vector or pixel graphics files to be used as patterns in the lithography process requires the licensed Lithography Option. For information on how to activate the scripting interface or the Lithography Option, refer to *Access Code* (page 249).

12.2: Performing lithography

Lithography can be performed provided that suitable samples, tips, and lithography parameters are used. Depending on the operating mode and operating parameters used during the Lithography process, the surface modifications fall into two distinct categories:

1. Mechanical surface modification through "scratching", "indenting" (both Static Force mode), or through "hammering" (Dynamic Force mode). This type of modification require higher tip-sample interactions then normally used during imaging to mechanically transfer the desired pattern into the sample surface. The width and depth of the scratches or indentations made mainly depend on the force exerted on the cantilever tip and on the tip's shape.
2. Electrochemical surface modification through voltage-dependent surface reactions. This type of modification requires a voltage difference between sample and tip, and will add molecules to the surface (e.g. through oxidation). The width and height of the oxidative surface modifications depend on the relative humidity of the ambient air, on the strength of the electric field, and on the tip speed.

A typical lithography process is performed as follows:

1. The sample surface is imaged to identify an area that is suitable for transfer of a pattern. Suitable areas should preferentially be flat and dust-free.
2. The Lithography window is opened and the "Load" button of the Lithography toolbar is clicked to import the imaged sample surface.
3. A pattern that was previously designed is imported. Suitable sources for patterns can either be (multi-layered) vector graphics files (GDS II, DXF, CIF, OAS, OASIS) or (multi-color/grayscale) pixel graphics files (BMP, DIB, GIF, TIFF, PNG, JPEG). After import of a vector or pixel graphics file, the pattern is referred to as a "Lithography object" in the Lithography window.

IMPORTANT

- In case of vector-based objects, multiple lithography objects may be present (e.g. through sequential import) and used for lithography. In case of pixel-based objects, only one pixel-based object can be present at any given time (other objects will be deleted upon import).
- A separate CAD program called "LayoutEditor" is included on the installation CD to create suitable GDS vector graphics (Newest version of LayoutEditor; http://layout.sourceforge.net). Pixel graphics files can be created or edited in any pixel-based image editor like the Windows Paint.
- As an alternative to designing the lithography pattern in a vector or pixel graphics file and then importing it into the lithography software, a freehand drawing mode is available in the Lithography window.

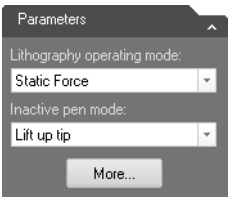
4. The imported object is positioned and scaled to fit the target area.
5. The Lithography sequence is executed.
6. The sample surface is re-imaged to view the Lithography results.

Tip

As alternatives to step 3–5, you can also use the Direct Tip Manipulation or Free Drawing modes.

12.3: Lithography panel

Parameters section



Lithography operating mode
Used to select the operating mode during lithography operation:. The following options are available:

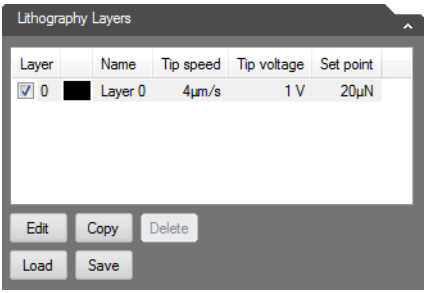
– **Static Force**
– **Dynamic Force**
– **STM (STM only)**

Inactive pen mode
Action to be performed when the tip is moving from one end point to a new start point, in case the end point and start point are not the same. The following options are available:

– **Lift up tip**
  Only lift the tip (upper position of the Z-actuator of the scan head). No feedback will be performed by the Z-Controller during travel to the new start point.
– **Standard operating mode**
  Switch the Z-Controller operating mode back to the one selected in the "Operating Mode Panel" during imaging. All values such as Tip speed, Tip voltage, Setpoint etc. will temporarily chance back to the values used for imaging. The Z-Controller will be active during travel to the new start point.

"More" button
Opens up the SPM Parameters dialog on the "Lithography" page (see *Section 12.7.1: Lithography page*).

Lithography Layers section



Layer list
Lists all layers that are present in the objects shown in the Lithography Objects list. Layer 0 is always present, even if no lithography objects exists, and may be used to set the default Lithography parameter values (see *Parameters* (page 202) in *Section 12.5.2: Pixel Graphic Import dialog* for details).

Edit
Edit will open the Layer Editor dialog to edit the selected layer.

Copy
Copy will open the Layer Editor dialog (see *Section 12.3.1: Layer Editor dialog*) to edit the selected layer before copying it. When changes have been made (if any) and the "OK" button is clicked, a new layer is generated.

IMPORTANT

Upon creation of a new layer, the layer number will be incremented to the next available layer number. If a total of 256 layers is reached, no more layers can be added.

Delete
Used to delete a layer. Delete will open a warning dialog to confirm the deletion of the selected layer.

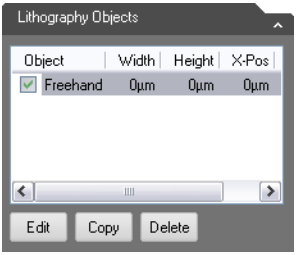
IMPORTANT

Only layers currently not assigned to any object can be deleted.

Load
Load a predefined layer list ".lld". Layers that are needed to display the current objects that are not part of the loaded list will be created.

Save
Save all the layers to a layer list file ".lld".

Lithography Objects section



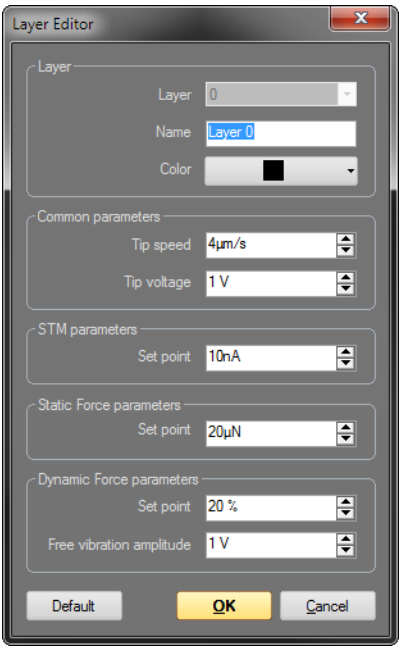
Contains a list of all available Lithography objects. Objects may be selected or deselected by checking or unchecking the checkbox. If the object is unchecked it will not be used for a lithography session.

Edit
Edit will open the Object Editor dialog to edit the selected object (see *Section 12.3.2: Object Editor dialog* (page 195)).

Copy
Copy will open the Object Editor dialog to edit the selected object before copying it.

Delete
Delete will delete the selected object. A warning dialog will appear for confirmation of this action.

12.3.1: Layer Editor dialog



The Layer Editor sets the controller parameter values to be used during lithography.

Layer

Layer
Displays the selected layer's number.

Name
Displays and allows editing of the selected layer's name.

Color
Allows selection of the layer color for display of the layer elements in the Topography chart of the Lithography window.

Common parameters

Tip speed
Determines the drawing speed during lithography,

Tip voltage
Determines the voltage set to the tip during oxidative Lithography.

STM parameters

Setpoint
Used to set the tunnelling current Setpoint of the Z-Controller during STM Lithography.

Static Force parameters

Setpoint
Used to set the force Setpoint of a lithography sequence performed in the Static Force AFM mode.

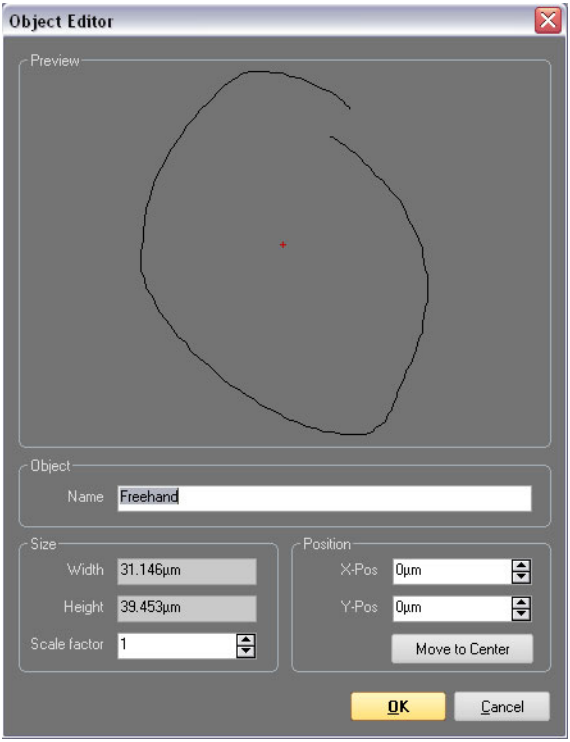
Dynamic Force parameters

Setpoint
Used to set the amplitude Setpoint of a lithography sequence performed in Dynamic Force AFM mode.

Free vibration amplitude
Used to set the Free vibration amplitude of a lithography sequence performed in Dynamic Mode

"Default" button
Loads the default Lithography parameter values.

12.3.2: Object Editor dialog



Preview

Graphical area that provides a preview of the selected Lithography object. The red cross (if visible) indicates the origin position of the object.

Object

Name
The name that is used to describe the object. Default names are generated during import, based on the GDS II object names, or on the pixel graphic filename, but may be edited here afterwards.

Size

Width/Height
Displays the width and the height of the object.

Scale factor
The factor by which the object can be scaled. If the scale factor is changed, the width and the height will be automatically recalculated. Scale factor 1 represents the original size.

Position

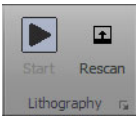
X-Pos/Y-Pos
The X-Pos and the Y-Pos may be used to move the object within the space of the topography map.

Move to Center
Moves the origin on the selected object back to the center of the topography map.

12.4: Acquisition tab

During Lithography, all groups of the Acquisition tab are identical to those during imaging of the sample, with the exception of the Imaging group, which is replaced by the Lithography group.

12.4.1: Lithography group



Start
Starts the lithography sequence and changes to “Stop” until the lithography sequence is finished. Clicking “Stop” aborts the sequence.

Rescan
Starts a single image measurement and changes to “Stop” until a full image has been scanned. The image is scanned from the bottom to top. Clicking “Stop” aborts the measurement.

IMPORTANT

When performing imaging from within the Lithography window, be sure to set valid imaging parameters in the Imaging and Z-Controller sections of the Imaging panel.

Launcher icon
The Lithography parameters can also be accessed through the "Dialog Launcher" icon (at the bottom right corner of the Lithography group), which opens up the SPM Parameters dialog on the Lithography page (see *Section 12.7.1: Lithography page*.

12.5: Lithography toolbar

Manipulate
Starts the direct tip manipulation mode. It is now possible to control the movement of the tip by moving the mouse around the topography color map chart. When the left mouse button is held down, Lithography will be performed with the lithography operating mode set in Lithography panel, and with the parameters set in Layer 0 (the Tip speed setting is ignored). When the left mouse button is released, the tip will go to the inactive pen mode set in the Lithography panel, and will not move until the left mouse button is pressed again. Dragging the mouse slowly will produce smoother lines than dragging it fast.

Draw
Starts the free hand drawing mode. A shape can now be drawn in the topography color map chart by clicking and holding the left mouse button. A shape can only consist of a single line. Repeating the above will erase the previous drawing. Double clicking the drawing will save it to the Lithography Object list. The drawn shape can be executed by a click on "Start" in the Acquisition tab.

Import vector
Opens an "Open File" dialog to import a GDS II vector graphic file (extension ".gds"). Other formats (DXF, OAS, OASIS, CIF) can be converted to GDS II using the external program LayoutEditor (provided on installation CD).

IMPORTANT

- Since the Lithography software only supports a subset of the GDS II file format, an error message will appear when a file containing non-supported elements is loaded.
- To avoid most load error messages, the vector graphics project should be fully flattened before saving it as a GDS II file. LayoutEditor and most other CAD programs provide some form of flattening functionality. Refer to the manual or (online) help of your CAD program for details.

For more information on the available import options after selecting a valid GDS II file, refer to *Section 12.5.1: Vector Graphic Import dialog*.

Import bitmap
Opens a "Open File" dialog for importing a BMP, DIB, GIF, TIFF, PNG, or JPEG pixel graphics file.

IMPORTANT

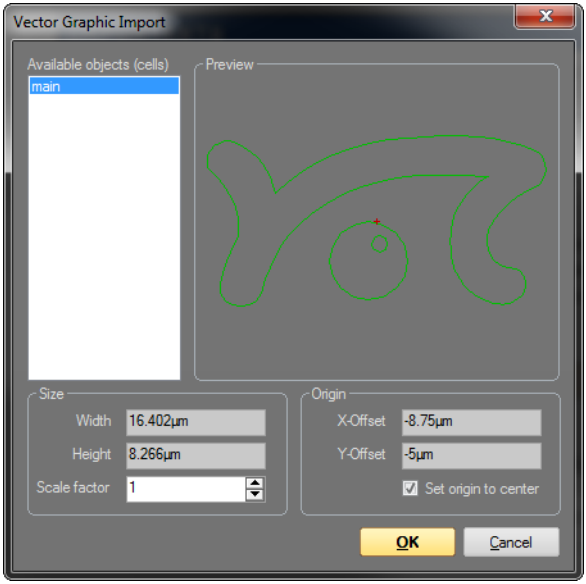
The Lithography software supports files with 256 pixels or less in width and height.

For more information on the available import options after selecting a valid pixel graphics file, refer to *Section 12.5.2: Pixel Graphic Import dialog*.

Load
Loads the Topography image from the Imaging window into the Lithography Topography chart.

Capture
This button captures the measurement currently displayed in the "Lithography window" to the History page of the Gallery panel. If clicked during a measurement, a copy is generated as soon as the measurement in progress is finished. The capture process is cancelled by clicking second time. The captured measurement is stored as a new document and remains open in the Document space of the SPM Control Software.

12.5.1: Vector Graphic Import dialog



The Vector Graphic Import dialog appears after clicking the “Import Vector” button and selecting a valid GDS II file. It can be used to select the object (cell) of the GDS II file to import. Size and origin of the resulting lithography object can be set during import using the Size and Origin fields (see description below), or after import using the Object Editor (see Section 17.3.2: The Object Editor dialog (page 191) for details).

Available objects (cells)

Contains a list with all valid objects (cells) of the selected GDS II file. Selecting an object will results in the respective object being displayed in the preview area of the Vector Graphic Import dialog, and will cause the selected object to be imported when the “OK” button is clicked. Objects can only be imported one at a time. Clicking the “Cancel” button will abort the import process.

Preview

A graphical area that displays the selected object in the available objects list (see above). The red cross (if visible) indicates the position of the object's origin.

Size

Width / Height
Displays width and height of the selected object (cell).

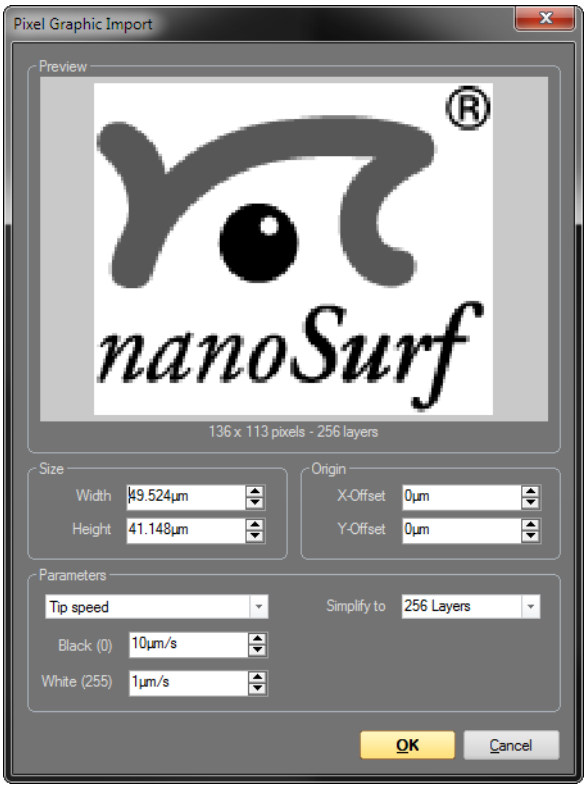
Scale factor
The factor by which the selected object (cell) will be scaled. A scale factor of 1 corresponds to the original object size. If the scale factor is changed manually, the object's width and height will be recalculated and displayed automatically.

Origin

X-Offset / Y-Offset
The X-Offset and the Y-Offset of the origin of the selected object (cell).

Set origin to center
When enabled, the origin of the object (cell) will be set to the center of the rectangle that encloses the object. When disabled, the origin will remain at the position that is defined in the object.

12.5.2: Pixel Graphic Import dialog



The Pixel Graphic Import dialog appears after clicking and selecting a supported pixel graphics file, and can be used to specify how such a file is converted to a lithography object. All images are first converted to an 8-bit grayscale (256 levels). Each set of pixels with the same grayscale value will correspond to a separate layer in the resulting lithography object. Layers will only be generated for those grayscale values that are actually occupied. In addition, the number of layers can be reduced upon import (see Simplify to (page 186)).

For each layer, individual lithography parameters can be set. One of these lithography parameters can be automatically varied upon import, by using the grayscale values of the imported pixel graphics file to define the selected parameter's range (see Parameters below). All parameters can of course always be modified manually after import (see Section 17.3.1: The Layer Editor dialog (page 188)).

Preview

Graphical area that displays the selected pixel graphics file and information about the file.

Size

Width / Height
The width and the height of the lithography object resulting from the Pixel Graphic import. The default settings for width and height are taken from the dimensions of the current color topography map of the Lithography window. The pixel graphic is automatically resized to fit into the area defined by these dimensions while maintain its aspect ratio. It is at this point however possible to change the automatically calculated size manually. If the width is changed manually, the height is recalculated to keep the aspect ratio. If the height is changed manually, the width is not recalculated.

Origin

X-Offset / Y-Offset
By default the origin is in the center of the pixel graphic. By manually changing X-Offset and Y-Offset, the origin may be moved to a different position.

Parameters

This area allows selection of the lithography parameter that will be automatically varied, based on the different grayscale values of the imported pixel graphics file. The parameter values for the black and white pixels of the imported pixel graphic can be set, after which the parameter values corresponding to any in-between grayscale values are interpolated.

IMPORTANT

Since it is only possible to select one automatically adjusted lithography parameter per import, the other parameters must be set elsewhere. This is achieved by setting the Layer 0 parameters before import. The values entered here will be used as default values for all imported layers, except for the parameter that was explicitly selected in the Pixel Graphics Import dialog.

All values and settings in the parameters section are stored when the dialog is closed. They will be automatically used the next time the dialog is opened.

From the drop-down list box, one of the following parameters may be selected for automatic calculation:

- **Tip speed**
- **Tip voltage**
- **STM Setpoint**

- **Static Force Setpoint**
- **Dynamic Force Setpoint**
- **Dynamic Force Amplitude**

Black / White
Used to enter the parameter values for black and white pixel values, which form the basis for the interpolation of the in-between color/grayscale pixel values.

Example

Setting the automatically adjusted Lithography parameter to "Static Force Setpoint", and Black (layer 0) and White (layer 3) to 25 µN and 10 µN, respectively, will result in:

- Layer 0 (black pixel layer) having a Static Force Setpoint of 25 µN
- Layer 1 (gray pixel layer 1) having a Static Force Setpoint of 20 µN
- Layer 2 (gray pixel layer 2) having a Static Force Setpoint of 15 µN
- Layer 3 (white pixel layer) having a Static Force Setpoint of 10 µN.

Simplify to
Select the number of layers the imported pixel graphics file should be simplified to. Selecting the number of layers to be identical to the number of grayscale values in the pixel graphics file will results in no simplification taking place. In all other cases, simplifications are performed through binning of layers.

12.6: Lithography preview

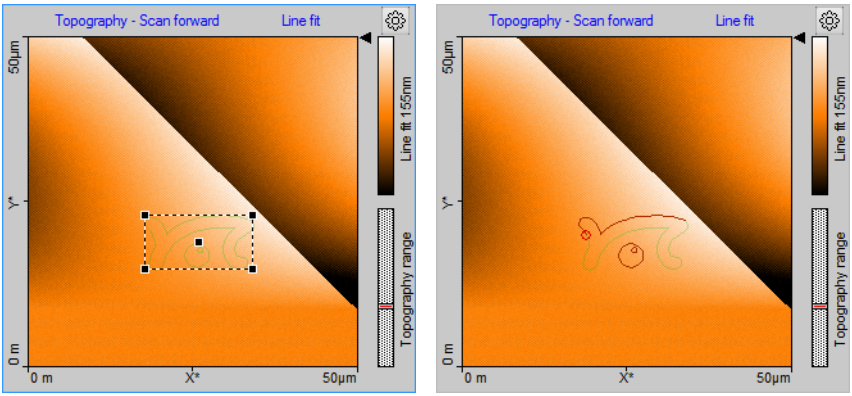


Figure 12-7: Lithography preview. (Left) Before the Lithography sequence has been started. (Right) While the Lithography sequence is running.

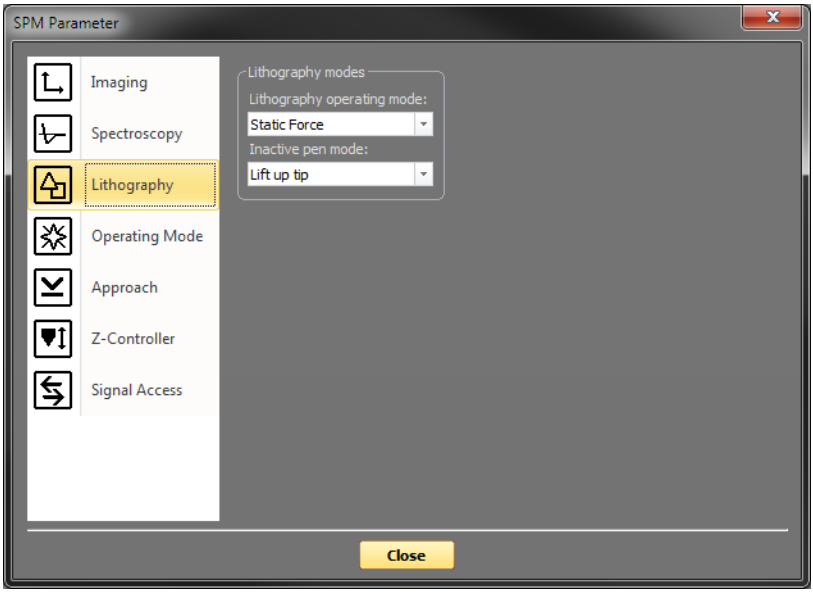
The Lithography Topography chart is the only chart present in the Chart area of the Lithography window (*Figure 12-7: Lithography preview*, left). It displays the topography image of the sample surface to be used for lithography (after the Topography information has been loaded via the "Load" button of the Lithography toolbar (see *Load* (page 192)) and the superimposed preview images of the Lithography objects (when these have been loaded and selected; see *Import vector* or *Import bitmap* (page 198)).

Before running a lithography sequence, a box with the size and content of the selected lithography object is superimposed on the surface map. When selecting the center of the box with the mouse, the corresponding object can be moved around the scan area to reposition it. The new object location (X-Pos and Y-Pos) is however only transferred to the object's properties (as displayed in the Lithography Objects list, and graphically shown on the Topography chart) when the selection box is double-clicked after repositioning. If it is not, any changes made are not implemented. Position of an object (and in addition its size) can also be modified by editing the respective parameters for the selected object inside the Lithography Object Editor dialog (see *Section 12.3.2: Object Editor dialog* (page 195)).

When a lithography sequence is started, the selection box will disappear, while a red circle and a darker red trace line will be drawn on the Lithography object preview to provide a live progress report on the Lithography drawing process (see *Figure 12-7: Lithography preview* (page 204), right). After a lithography sequence has been completed, the red line and circle will remain visible until a new lithography sequence is started.

12.7: SPM Parameters dialog

12.7.1: Lithography page



Lithography modes

Lithography operating mode
Used to select the operating mode during lithography operation. The following options are available:

- **Static Force**
- **Dynamic Force**
- **STM (STM only)**

Inactive pen mode
Action to be performed when the tip is moving from one end point to a new start point, in case the end point and start point are not the same. The following options are available:

- **Lift up tip**
  Only lift the tip (upper position of the Z-actuator of the scan head). No feedback will be performed by the Z-Controller during travel to the new start point.

– **Standard operating mode**
  Switch the Z-Controller operating mode back to the one selected in the "Operating Mode Panel" during imaging. All values such as Tip speed, Tip voltage, Setpoint etc. will temporarily chance back to the values used for imaging. The Z-Controller will be active during travel to the new start point.

Chart automation

Auto chart settings
If checked, the chart arrangement is automatically updated (see also *Auto chart settings* (page 206)).

Auto Capture
If checked, all Lithography measurements are automatically stored in the history Gallery. If unchecked, you have to click the "Capture" button in the Lithography tool bar to manually save your measurement data.

CHAPTER 13:

Working with documents

13.1: Introduction

When working with the Nanosurf SPM Control Software, all finished measurements (a full image was recorded) will be temporarily stored according to the file name mask you specified in the Gallery panel (see *Section 13.4: Gallery panel*). These measurement documents can be opened and displayed in the document area of the SPM Control Software's workspace (see *Section 7.1: General concept and layout* (page 76) and *Section 7.4: Document space* (page 80)). It is strongly recommended to permanently store relevant documents to a new folder (see *Save as* (page 220) in *Section 13.4.3: Gallery toolbar*).

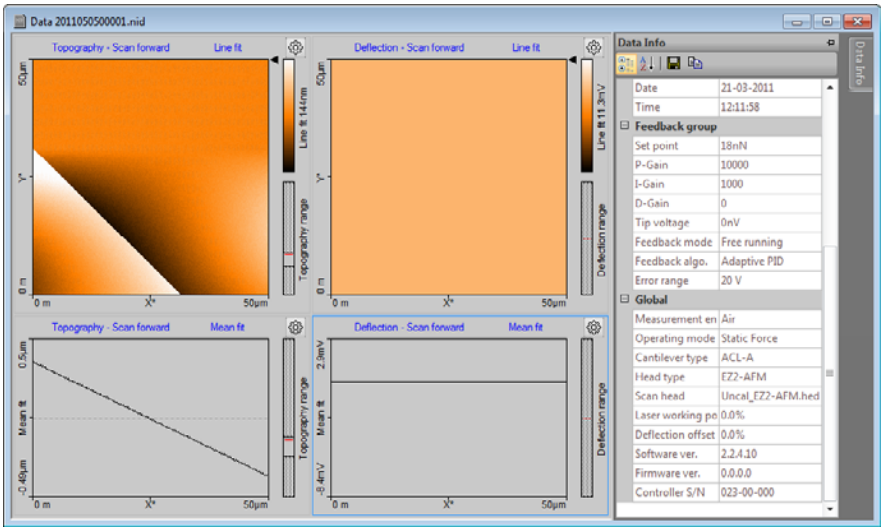


Figure 13-1: Measurement document. Typical measurement window with the Data Info panel expanded (see *Figure 7-4: Example of a measurement document window* (page 80) for a window with a minimized Data Info panel).

Charts and the Data Info panel together display all available measurement information.

13.2: Data Info panel

The Data Info panel (minimized by default, but expanded upon hovering of the mouse cursor over the Data Info tab on the right side of the measurement document window) displays measurement settings and the hardware used during the measurement. Its content is self-explanatory and will therefore not be discussed in this manual.

Just like the panels of the Info pane, the Data Info panel can be “pinned” and “unpinned” to disable or enable the Auto-hide function of the panel (see *Section 7.5: Panels* (page 81)). It cannot be undocked from the document window, however.

The Data Info panel also contains a small toolbar, which allows you to customize the presentation of the data and offers ways to export it.

13.2.1: Data Info toolbar

Categorized
The “Categorized” button ( ) will group the data entries for the measurement document by category. This is the default display method of the Data Info panel.

Alphabetical
The “Alphabetical” button ( ) will sort the data entries for the measurement document alphabetically.

Save
The “Save” button ( ) will save the information in the Data Info panel to file. Possible formats are text (.TXT) and comma separated values (.CSV) files.

Copy to Clipboard
The “Copy to Clipboard” button ( ) will copy the entries of the Data Info panel to the Windows clipboard for easy pasting into other applications.

13.3: Charts

Charts provide a graphical display of the measured data. Charts occur in Measurement document windows, in Operating windows, and in various other windows and dialogs. You can adjust them to your needs and liking. How to do this is explained in this section. This information is valid for charts in stored measurement documents as well as for ongoing measurements in one of the Operating windows (*Imaging*, *Spectroscopy*, and *Lithography*).

A Chart consists of a graphical representation of the measured data itself and elements that provide additional information. There are three basic chart types: Line graph, color map and 3D view (see *Figure 13-2: Elements of a chart*, items 1–3).

Chart titles

The title elements of each chart display the signal name and the background line filtering type that are used. A click on each of these titles opens a drop-down menu with other possible signals or filters:

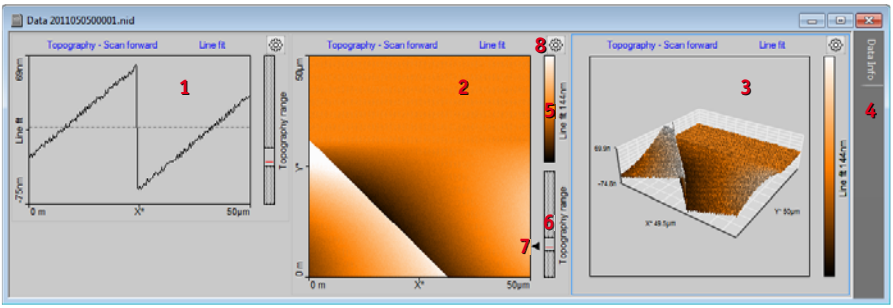
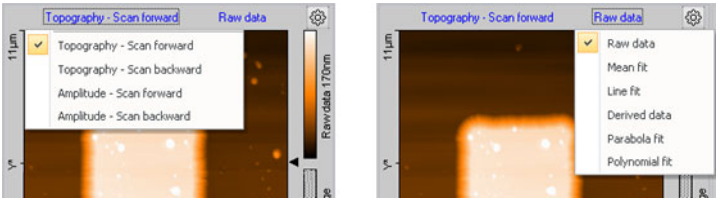


Figure 13-2: Elements of a chart. (1) Line graph. (2) Color map. (3) 3D view. (4) Data Info panel (see *Section 13.2: Data Info panel*). (5) Color scale for data Z-range. (6) Data range indicator, with scan head Z-range as dotted box, data Z-range as solid gray box and current scan line height as red line. (7) Line selection arrow. (8) "Chart Properties" button.



Changing the titles will change the content of the chart.

Color scales

The Color scale (*Figure 13-2: Elements of a chart*, item 5) shows which measured signal level is mapped to which color. The color mapping can be changed using the Color Palette dialog (see *Section Color Palette* (page 245)) .

Data range indicator

The Data range indicator (*Figure 13-2: Elements of a chart*, item 6) shows the Z-range of the scan head and of the values occupied by the measured data, and the current scan line height.

Hovering with the mouse cursor over the Color scale or Data range indicator of a color map chart opens a height histogram graph and two range selectors:

This histogram displays the current height distribution of the measurement data and the used color range. With the top and bottom range selectors, the color bar range can be adjusted to the actual height distribution of the measurement data. Changing these range settings changes the "Center" and "Span" parameters of the Chart Properties dialog (see *Section 13.3.2: Chart Properties dialog*) and immediately updates the color display of the data in the chart.

Line selection arrow

With the Line selection arrow (*Figure 13-2: Elements of a chart*, item 7) the shown data line on line charts displaying the same signal can be changed by holding down the left mouse button over the arrow and move the mouse up or down.

Chart properties

The "Chart Properties" button (; *Figure 13-2: Elements of a chart*, item 8) opens the Chart properties dialog. This dialog is the center of all chart parameters and is described in more detail in section *Section 13.3.2: Chart Properties dialog*.

Most chart settings can also be accessed from a context menu, which is opened by right-clicking a chart.

13.3.1: Working with multiple charts

In some windows, multiple charts can be displayed and configured by the user at anytime (e.g. in the Imaging window or a Document window). The same signal can be displayed in different styles (e.g Line Graph and Color map) and / or multiple signals can be shown side by side (e.g. Topography and Phase Signal).

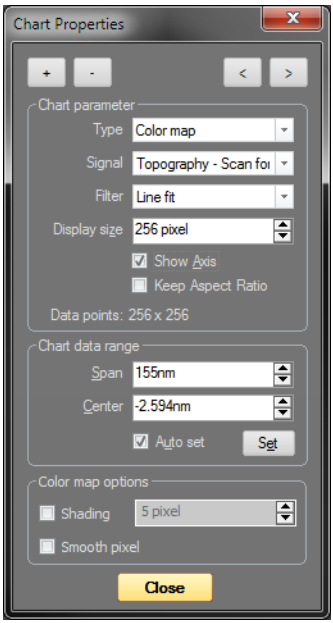
Adding or removing a chart, or setting chart parameters is all performed in the Chart Properties dialog (see *Section 13.3.2: Chart Properties dialog*). When opened, the settings displayed in the Chart Properties dialog refer to the currently selected chart. This (active)

chart is indicated by a thin blue line around the chart area. A chart is activated by clicking on it with the mouse cursor anywhere in the chart area.

Arrangement of the charts is performed automatically by the control software based on the size of the window and based on the order in which the charts were generated/added. If the window is to small to display all charts, scrollbars are displayed at the border of the window.

Short cuts to add and remove charts are found in the chart context menu. Select “Create new chart” or “Delete current chart” from the menu list. It is also possible to use the “Insert” or “Delete” key of your computer’s keyboard for this task. In all Operating windows, “Add Chart“ and “Remove Chart” buttons (“+” and “–”) can be found in the respective measurement toolbar.

13.3.2: Chart Properties dialog



The Charts Properties dialog is used to set all chart properties that influence data display by the respective chart. It may be kept open at all times if many parameters have to be set for different charts.

Some parameters are chart type specific. They are therefore displayed at the bottom of the Chart Properties dialog in a separate group.

Add chart

The “Add Chart” button (+) creates a copy of the currently selected or active chart and adds it to the active window in last position.

Remove chart

The “Remove Chart” button (-) removes the currently active chart.

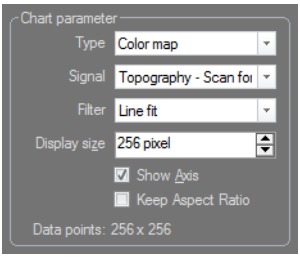
Previous chart

The “Previous Chart” button (<) activates the previous chart and updates the parameters displayed in the Chart Properties dialog to those of that chart.

Next chart

The “Next Chart” button (>) activates the next chart and updates the parameters displayed in the Chart Properties dialog to those of that chart.

Chart parameters



Type
Selects the chart type to be used for display of the measurement data:

– **Line graph**
Data is displayed as a line plot. Points outside the range of the scanner are displayed in red. The line being displayed is selected by dragging the Line selection arrow in a Color map (see *Line selection arrow* (page 211)). In ongoing measurements (e.g. during imaging) the position of the Line selection arrow is updated automatically and corresponds to the last measured scan line (but even here it is possible to select a different line for view in a line graph by dragging/holding the Line selection arrow in a different location).

– **Color map**
Z-height data is encoded using a color scale and displayed 2-dimensionally.

– **3D view**
  Data is shown in a 3-dimensional representation in parallel perspective. Color information (such as implemented in the Color map) is maintained.

Signal
Selects the input channel (signal data) to be used for the chart. The available signals depend on the operating mode (selected or used) and the status of the User inputs.

Filter
Selects the line filter method. The control software applies this filter to the measured data before displaying it (see *Figure 13-3: Data filter types*). No modification of the original measurement data occurs (selecting another filter is always possible). Available data filters are:

– **Raw data**
  No data processing.
– **Mean fit**
  Calculates the mean value of each line of data points and subtracts this number from the raw measurement data for each data point of that line.
– **Line fit**
  Calculates the first order least squares fit (mean value and slope) for each line of data points and subtracts the fitted values from the raw measurement data for each data point of that line.
– **Derived data**
  Calculates the difference between two consecutive data points (derivative) and displays this instead of the raw image data.
– **Parabola fit**
  Calculates the second order least squares fit for each line of data points and subtracts the fitted values from the raw measurement data for each data point of that line.
– **Polynomial fit**
  Calculates the fourth order least squares fit for each line of data points and subtracts the fitted values from the raw measurement data for each data point of that line.

Display size
The size of the chart in pixels.

Show Axis
When checked (default), the axis labels, color and range scales, and titles are displayed alongside the graph. When unchecked, they are hidden.

Keep Aspect ratio
When checked, the axis in the color map are drawn in their correct size-relation (according to their value and unit). When unchecked (default), the size of the display is always a square and data pixels are stretched if necessary.

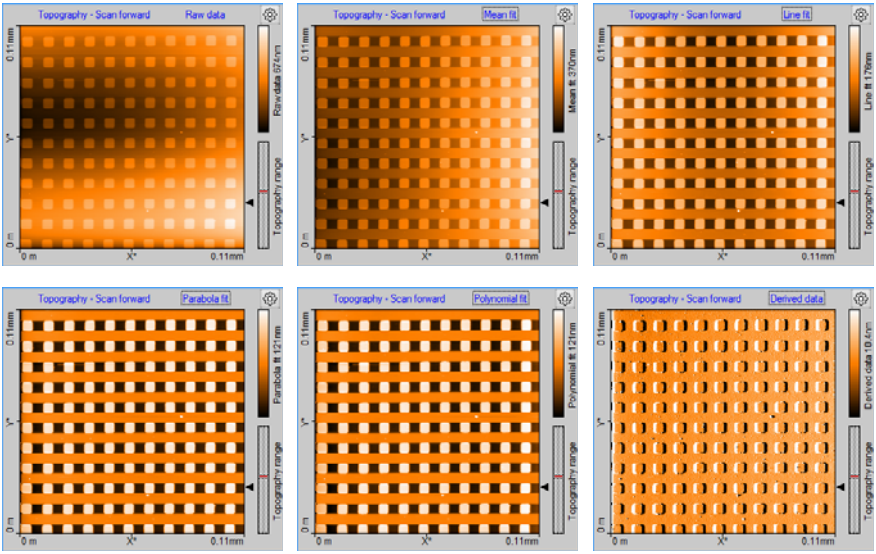
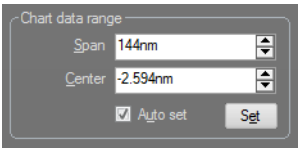


Figure 13-3: Data filter types. The same measurement data displayed using the available filters. A defective area on a calibration grid is shown here to illustrate the effect of the filters.

Chart data range



Span

The span that corresponds to the chart's displayed Z-range. Increasing Span decreases feature contrast and vice-versa. The current span is displayed next to the color scale in color maps, or can be inferred from the Z-axis labels in Line graphs and 3D views.

Center

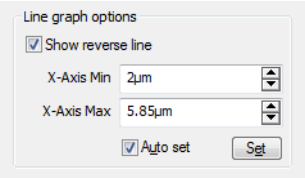
The signal value that corresponds to the center of the "Span" parameter.

Auto set

When checked, the chart's Z-range is automatically set to optimally match the measurement data. During measurements, the Span and Center parameters will be updated continuously (i.e., the chart adapts to the available data).

Set button
Clicking this button starts the optimization of the Z-range manually. Mostly used when "Auto set" is off.

Line graph options



Show reverse line
When checked, the reverse scan data is drawn in gray (see *Figure 13-4: Show reverse line option*. It allows comparison of the forward and reverse measurements data. Whether or not this data is available depends on the measurement mode used during the acquisition of the data (see *Measurement mode* (page 161).

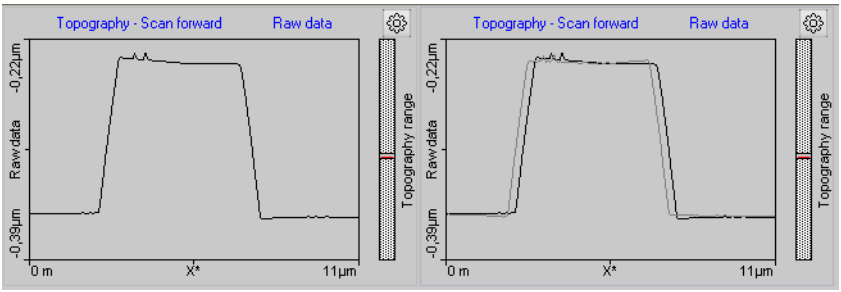
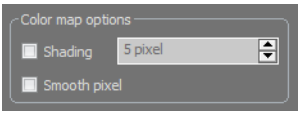


Figure 13-4: Show reverse line option. (Left) Reverse line disabled. (Right) Reverse line enabled.

X-Axis Min
Defines where the X-axis will start. Can be used to zoom in or out to a specific data range.

X-Axis Max
Defines where the X-Axis will end. Can be used to zoom or out to a specific data range.

Color map options



Shading
When checked, the color map creates the impression of a 3-dimensional surface which is lighted from the left. This is achieved by combining the topography with its derivative. The number of pixels in the edit box defines the amplification of the derivative add on.

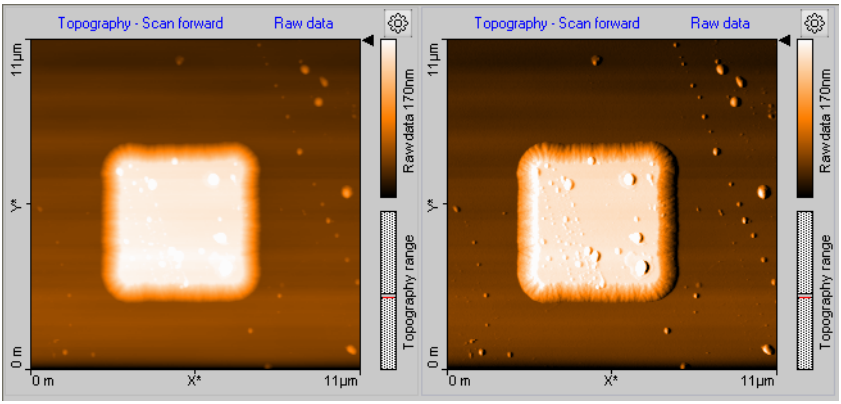
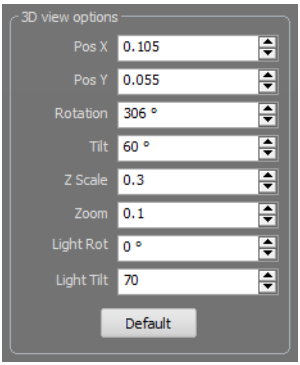


Figure 13-5: Shading option. (Left) Shading disabled. (Right) Five-pixel shading enabled.

Smooth pixel
When checked, the screen edge rendering of individual data pixels is smoothed with their neighboring pixels. Alternative data pixels are drawn as individual squares. This smoothing shows the most effect when the display size is larger that the number of measured of data points (e.g. a 256×256 measurement displayed at 512×512 pixels).

3D View options



Pos X, Pos Y
Defines the center position of the 3D plot inside the chart area.

Rotation
Defines the z-axis rotation of the 3D plot relative to the view point.

Tilt
Defines the off-plane angle of the 3D plot.

Z-Scale
Defines a Z-axis 'stretch' factor. Use this e.g. to enlarge surface details.

Zoom
Defines the magnification of the 3D plot.

Light Rot
Defines the rotation angle of the light source relative to the Z-axis (360°)

Light Tilt
Defines the off-plane angle of the light source. The lowest value (0°) corresponds to "sunset" lighting, the highest value (90°) corresponds to mid-day lighting at the equator.

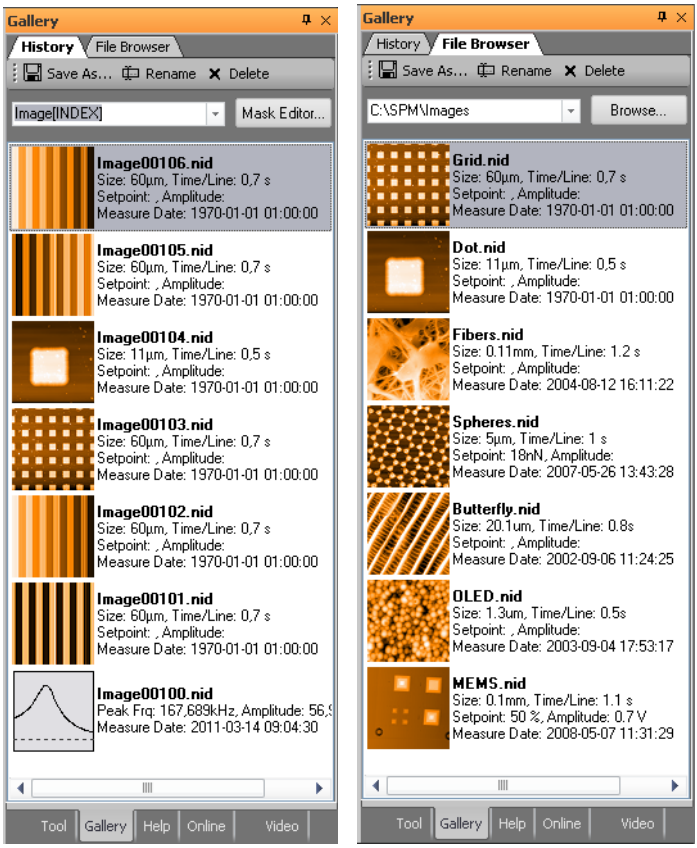
Default
The "Default" button resets all 3D parameters to their default values.

Keyboard and Mouse short cuts
Always click and hold the left mouse button on the 3D view chart while moving around the mouse to change the 3D view. The surface is reduced in feature complexity once the left mouse button is pressed to speed up redrawing on the screen. The surface will return to full detail once the mouse button is released.

Press the following additional keys/buttons to determine which chart property is changed:

- **Surface rotation**
  Mouse left/right
- **Surface tilt**
  Mouse up/down.
- **Size displayed surface**
  "Ctrl"- key + mouse up/down
- **Surface position**
  "Shift"-key + mouse up/down/left/right
- **Z-scale magnification**
  Left mouse button + right mouse button + mouse up/down
- **Light source direction**
  "Shift" + "Ctrl"-key + mouse left/right
- **Light source height**
  "Shift" + "Ctrl"-key + mouse up/down

13.4: Gallery panel



The Gallery Panel displays lists of thumbnails representing previous measurements for quick access to those documents. It contains two pages: the “History” page, with the temporarily (automatically) stored measurements (for details on how to change the default History folder and the maximum number of files to be stored see *Gallery Settings* (page 248)) and the “File Browser” page with measurements from a user-selected directory (e.g. containing older measurements that were previously moved there). The various elements of the Gallery panel are described in the next sections.

13.4.1: History File mask

The temporary (automatic) storage of new measurements uses a File mask to create new file names each time a new measurement has to be saved. This mask can contain normal text, but also special variables like index number or date and time stamps. You may enter a new mask directly into the edit field in the History page, select an old mask from the drop-down menu, or define a new mask with the help of the Mask Editor dialog (see *Section 13.4.4: Mask Editor dialog*), which is opened by clicking the "Mask Editor" button next to the edit box.

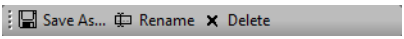
13.4.2: Image list

In the Image list the stored measurement are shown. Each measurement is displayed as a thumbnail image of the measurement, together with some information about the measurement and measurement document.

The following mouse operations are possible inside the image list:

- **Double-click**
  Opens the respective measurement in the document space.
- **Single left mouse click**
  Selects the respective measurement and removes all other selections.
- **"Ctrl" key + left mouse click**
  Adds individual selections to the current selections.
- **"Shift" key + left mouse click**
  Selects all measurements from the last selection to the new selection.

13.4.3: Gallery toolbar



The Gallery toolbar is present in both the "History" and "File Browser" pages. It performs similar functions in both pages.

Save as
Selected measurements can be saved to a new location with this button.

If only a single measurement is selected a standard Windows "Save" Dialog is shown. Here you select the new location and the new file name.

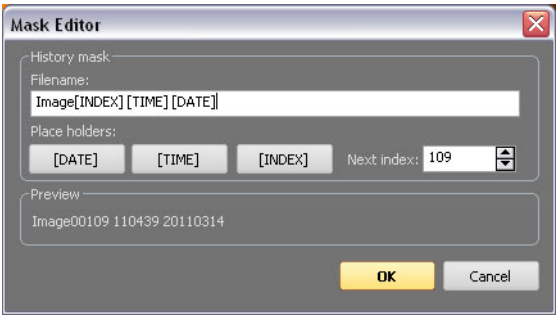
If multiple measurements are selected a "Folder" dialog is shown, which allows you to select (or create) the folder that all selected files are to be copied to. It is strongly

recommended to do this for files in temporary storage of the History folder that you want to keep, because they may be overwritten as soon as the maximum number of files in the History folder is reached (see *Section Gallery Settings* (page 248)

Rename
Single or multiple measurements can be renamed by clicking the "Rename" button. It will open the File Rename dialog (see *Section 13.4.5: File Rename dialog*), which allows you to specify a mask for the new file names.

Delete
Single or multiple measurements can be deleted by clicking this button.

13.4.4: Mask Editor dialog



The Mask Editor dialog assists you in the creation of file name masks.

History mask

Filename
A file name mask is the template that is used to generate the file names for documents that are temporarily stored (automatically) during measurement. A file mask consists of standard text entered by the user and of variables for software-generated text or numbers (either specified by the user or added automatically).

Mask variables
Mask variables can be entered as specific words surrounded by square brackets. The following variables are defined in the SPM Control Software:

– **[INDEX]**
This variable represents a number that is automatically incremented each time a new filename is created. The index number is 5 digits in length and filled with zeros for missing digits. The next index number that will be used is shown in the "Next Index" field.

– **[TIME]**
  This variable represents the actual time of file name creation. It is formatted with two digit numbers for the hours, minutes and seconds (HHMMSS). This time format is used regardless of the Regional Settings of the Windows operating system.
– **[DATE]**
  This variable represents the date of the day the file was created (i.e., the day the measurement was performed). It contains four digit numbers for the year and two digit numbers for month and day (YYYYMMDD). This date format is used regardless of the Regional Settings of the Windows operating system.

To quickly insert a Mask variable at the current cursor position in the mask edit box, click the corresponding button.

Next Index
This entry field defines the next index number to be used. By default this value is identical to the highest number present in the History files, increased by one.

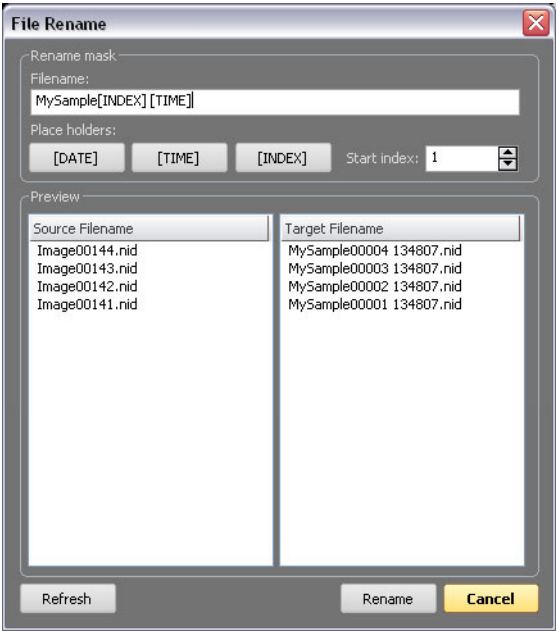
IMPORTANT

If no Mask variable is used, an index is automatically added to the text string defined in the filename mask.

Preview

The filename that will be used for the next measurement document to be saved (as specified by your entries) is shown here.

13.4.5: File Rename dialog



The File Rename dialog is used to rename (or move) multiple files using a Rename mask (see below). The dialog is opened by clicking the "Rename" button in the Gallery panel. To rename a file or multiple files, the Rename mask can be defined here following the same principles as for the History mask. A preview of the new filenames is shown in the preview section.

Rename mask

See *History mask* (page 221).

Preview

Source Filename
The left column of the Preview section shows the original filename(s).

Target Filename
The right column of the preview section shows what the filename(s) will be after pressing the "Rename" button.

Refresh
This button updates the preview list.

Rename
This button renames the selected files.

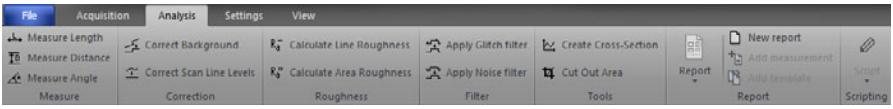
IMPORTANT

If no unique filename(s) would result from the specified Rename mask, an index is automatically added to the files. If this still does not result in unique filenames, the text "Copy of" is added to each filename as often as is required to make it unique.

Cancel
This button closes the dialog without renaming the files.

13.5: Analysis tab

Measurement data can of course not only be displayed in charts, it can be analyzed as well. The control software has several tools that allow quick numerical evaluation and modification of chart data in Operating or document windows. These tools are accessible through the various groups of the Analysis tab.



All of these tools can also be used while a measurement is still being acquired.

To use a quick evaluation tool:

1. Click on the chart that you want to evaluate to activate it.
2. Select the desired tool using one of the following approaches:
   - Click on one of the tool buttons in the Analysis tab.
   - Select the tool from the Chart's context menu (right-click on the chart).
3. Define the evaluation. The procedure to define the evaluation is different for each tool. Details can be found in the tool-specific instructions below.

When a tool has been selected, the Tool panel (see *Section 13.6: Tool panel*) moves to the top of the panel stack of the Info pane.

IMPORTANT

Depending on the selected chart type, some tools may be unavailable.

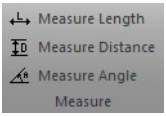
To stop using a tool:

➔ Select another tool, select the same tool a second time, or select “Abort” in the Chart’s context menu.

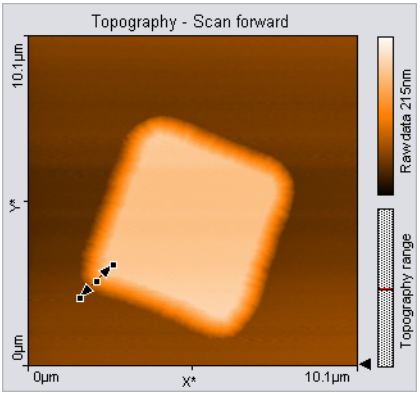
Tip

For more elaborate evaluations, the optional Nanosurf Analysis or Nanosurf Report software can be used.

13.5.1: Measure group



Measure Length



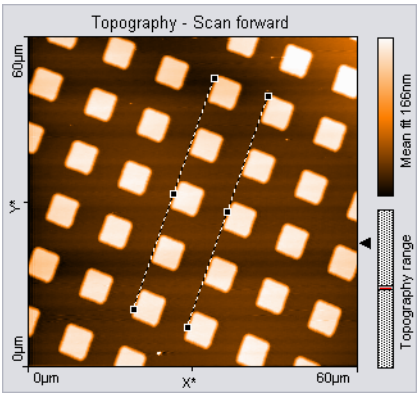
Calculates the distance and signal difference between two points. Graphically, a line with arrowheads on each end represents the selection marker. The line is defined by drawing a line on the measurement chart. The first point is positioned by moving the mouse cursor to the desired location and clicking and holding the left mouse button. The second point is positioned when the mouse button is released. When the mouse is not moved between clicking and releasing, an line parallel to the X*-axis is drawn.

The direction and length of the selection marker can be adjusted by dragging the end markers. The line can be moved as a whole by dragging the center marker.

The Tool status section of the Tool panel displays the calculated “Length”, “DeltaZ”, “Width” and “Height”. This data will also be stored in the “Tool” data category of the Data Info panel

(see *Section 13.2: Data Info panel*) for the respective measurement document as long as the tool is active when the document is stored. For more information on the data in the Tool status section (see *Tool status section* (page 237)).

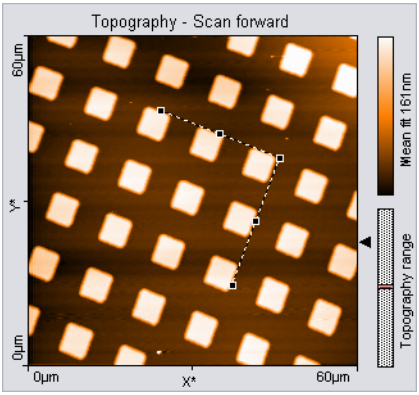
Measure Distance



Calculates the distance between two parallel lines. The parallel lines are defined by drawing them in the chart. The first point of the first line is defined by the mouse cursor position where the left mouse button is clicked, the second point by the position where the button is released. When the mouse is not moved between clicking and releasing, a line parallel to the X*-axis is drawn. After releasing the mouse button, a second parallel line sticks to the mouse cursor, that is released by clicking its desired position. The direction of the parallel lines can be adjusted by dragging their end markers; they can be moved by dragging the center marker.

The Tool status section of the Tool panel displays the calculated distance. The distance value only depends on the cursor positions, it does not on depend the displayed data values. The distance data will also be stored in the "Tool" data category of the Data Info panel (see *Section 13.2: Data Info panel*) for the respective measurement document as long as the tool is active when the document is stored. For more information on the data in the Tool status section (see *Tool status section* (page 237)).

Measure Angle

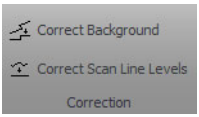


Calculates the angle between two lines. In Line graph-type displays, this tool can only be used when the chart displays data that has the unit "meters".

The two lines are defined by drawing them in the chart. The first point of the first line is defined by the mouse cursor position where the left mouse button is clicked, the second point by the position where the button is released. When the mouse is not moved between clicking and releasing, a line parallel to the X*-axis is drawn. After releasing the mouse button, the end of the second line sticks to the mouse pointer. The end is released by clicking its desired position. The angle can be changed by dragging the line end point markers or the corner mark; it can be moved by dragging the line center markers.

The Tool status section of the Tool panel displays the calculated angle. This data will also be stored in the "Tool" data category of the Data Info panel (see *Section 13.2: Data Info panel*) for the respective measurement document as long as the tool is active when the document is stored. For more information on the data in the Tool status section (see *Tool status section* (page 237)).

13.5.2: Correction group



In contrast to the evaluation tools of the Measure and Roughness groups, the tools of the Correction group (and also those of the Filter group (see *Filter group* (page 231)) actually change measurement data. This is done in a copy of the original measurement document, though, so you won't lose any data and will always be able to access the original measurement data in addition to the corrected or filtered data.

Correct Background

Removes the effect of an ill-aligned scan plane when the line filter options (see *Filter* (page 214)) do not give satisfactory results. This may be the case when the scan lines in different parts of the measurement have a different average height. An example of such a measurement is shown in *Figure 13-6: Correct Background*.

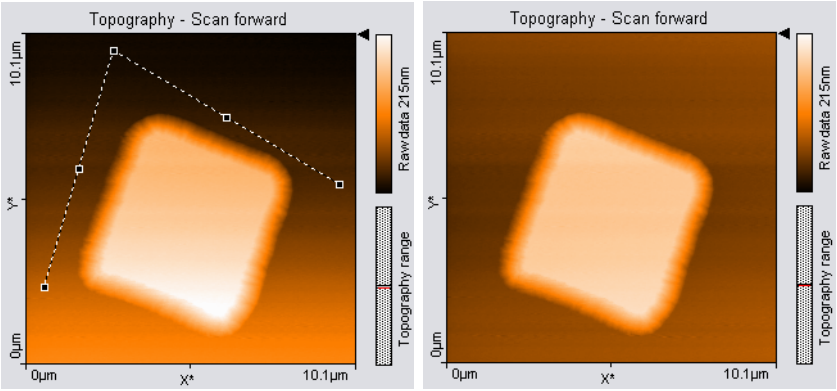


Figure 13-6: Correct Background. (Left) Uncorrected image; the end points of the selection marker have been moved to points that should have the same height. (Right) Corrected image.

To use the tool, select three points that should be on the same height. This is done in the same way as with the angle tool (see *Measure Angle* (page 339)). The selected points become the end points of the selection marker.

After clicking the "Execute" button in the Tool status section of the Tool panel, a copy of the original measurement document is made and the plane that is defined by the selection maker is subtracted from the measurement data in the newly created document. To get useful results, the Data filter option for the corrected image in the new document will be automatically set to "Raw data".

Correct scan line levels

Removes the effect of drift when the line filter options (see *Filter* (page 214)) do not give satisfactory results. This may occur when the scan lines in different parts of the measurement have a different average height. An example of such a measurement is shown in *Figure 13-7: Correct scan line levels*.

To use the tool, draw a line through points that should have the same height in the same way as with the Measure Length tool.

After clicking the "Execute" button in the Tool status section of the Tool panel, a copy of the original measurement document is made and the average level of each scan line in the newly created document is adjusted so that all points along the drawn line have the same

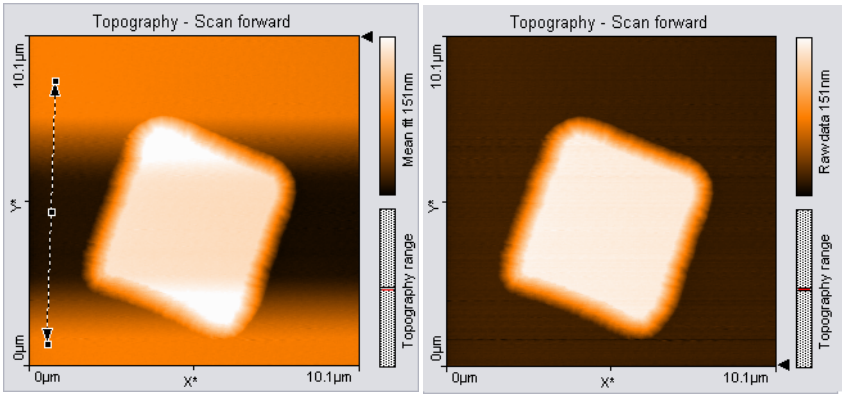
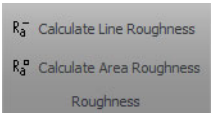


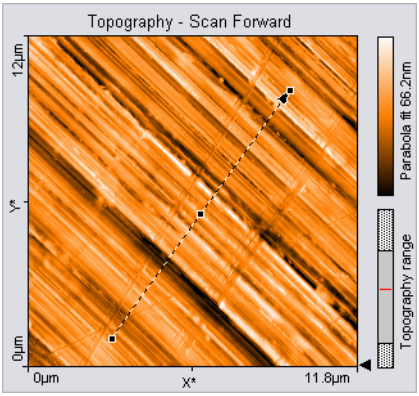
Figure 13-7: Correct scan line levels. (Left) Uncorrected image with a selection marker through points that should be at the same height. (Right) Corrected image

height. To get useful results, the Data filter option for the corrected image in the new document will be automatically set to "Raw data".

13.5.3: Roughness group



Calculate Line Roughness
Calculates several roughness parameters from the data at points along a selected line. The line is selected in the same way as with the Measure length tool (see *Measure Length* (page 225).



The Tool status section of the Tool panel displays the calculated "Length" and "DeltaZ" of the selected area.

The Tool result section displays the roughness values that are calculated from the data according to the following formulas:

The Roughness Average, S_a

$$S_a = \frac{1}{N}\sum_{l=0}^{N-1} | z(x_l) |$$

The Mean Value, S_m

$$S_m = \frac{1}{N}\sum_{l=0}^{N-1} z(x_l)$$

The Root Mean Square, S_q

$$S_q = \sqrt{\frac{1}{N}\sum_{l=0}^{N-1} (z(x_l))^2}$$

The Valley depth, S_v

S_v = *lowest value*

The Peak Height, S_p

S_p = *highest value*

The Peak-Valley Height, S_y

$S_y = S_p - S_v$

The roughness values depend on the line filter option (see *Filter* (page 214)) that is applied to the chart, because they are calculated from the filtered data.

Clicking the "Store" button in the Tool result section stores the roughness values in the "Roughness" data category of the Data Info panel for the active measurement document.

Calculate Area Roughness

Calculates several roughness parameters from the data points in a selected area.

The area is selected in the same way as with the Cut out Area tool.

The Tool status section of the Tool Results panel displays the calculated Size or Width and Height of the selected area. For more information on the Tool status section, see The Tool status section (page 207).

The Tool result section displays the roughness values that are calculated from the data according to the following formulas:

The Roughness Average, S_a

$$S_a = \frac{1}{MN} \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} | z(x_k, y_l) |$$

The Mean Value, S_m

$$S_m = \frac{1}{MN} \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} z(x_k, y_l)$$

The Root Mean Square, S_q

$$S_q = \sqrt{\frac{1}{MN} \sum_{k=0}^{M-1} \sum_{l=0}^{N-1} (z(x_k, y_l))^2}$$

The Valley depth, S_v

S_v = *lowest value*

The Peak Height, S_p

S_p = *highest value*

The Peak-Valley Height, S_y

$S_y = S_p - S_v$

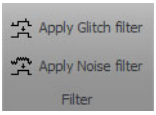
The roughness values depend on the Data filter that is applied to the chart, because they values are calculated from the filtered data. More information on data filters is provided in Section 18.2: The Chart bar under Data filter (page 199).

Clicking the "Store" button in the Tool result section stores the roughness values in the "Roughness" data category of the Data Info panel for the active measurement document.

Tip

The Area Roughness tool can be used to determine the mean height difference between two plateaus with more accuracy than with the "Measure Distance" tool. To determine the mean height difference, select an area on each plateau, and calculate the difference between their Sm-values.

13.5.4: Filter group



Glitch Filter

The Glitch Filter removes the effect of small defects in the image such as single short glitches in the scan. Compared to the Noise Filter (see below), it has the advantage of not reducing resolution on step edges. The glitch filter is implemented as a Median filter on a 3×3 pixel matrix.

To apply the filter, activate the color map chart that is to be filtered, then click the "Glitch Filter" button. A new Measurement document with the filtered data is created.

Noise Filter

The Noise filter removes high frequency noise from the image, but applying the filter will also decrease the resolution of the image. The Noise Filter is implemented as a convolution with a 3×3 pixel Gaussian kernel function.

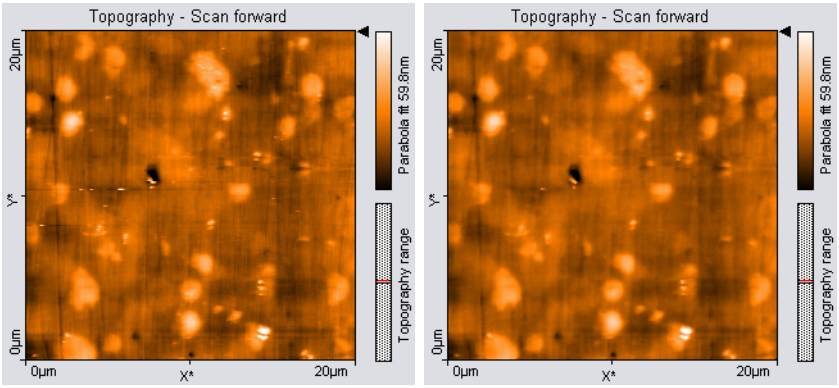


Figure 13-8: Glitch Filter. (Left) Unfiltered image with some glitches where the tip lost contact with the sample. (Right) Corrected image.

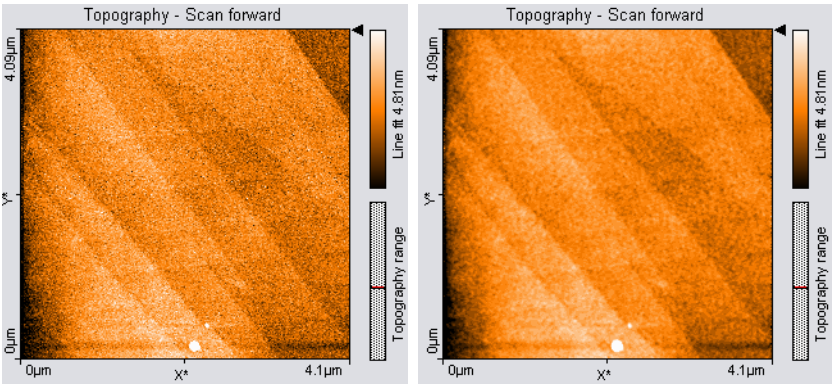


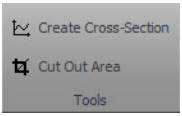
Figure 13-9: Noise Filter. (Left) Noisy (unfiltered) image of an AFM measurement on HOPG. (Right) Filtered image

To apply the filter, activate the color map chart that is to be filtered, then click the "Noise Filter" button in the Tools bar. A new measurement document with the filtered data is created.

Tip

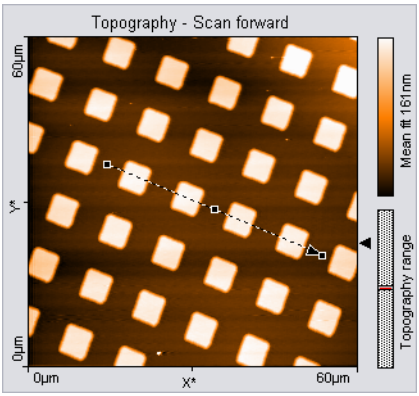
- Filters are especially useful for improving the appearance of 3D views.
- Applying filters may changes the result of the other tools. This may result in incorrect results, e.g. when evaluating sample roughness.

13.5.5: Tools group



Create Cross-Section
Creates a new measurement document containing a line cross-section of a Color map or Line View display.

The line is defined by drawing a selection arrow. The arrow points toward the forward direction of the line. The start of the arrow is defined by the mouse cursor position where the left mouse button is clicked, the end of the arrow by the position where the button is released. When the mouse is not moved between clicking and releasing, an arrow ending in the center of the measurement is drawn. The direction of the arrow can be adjusted by dragging its end markers; it can be moved by dragging the center marker.



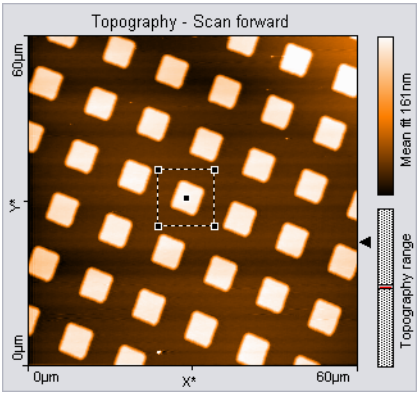
Double-clicking the graph, or clicking the "Cut out line"-button in the Tool status section of the Tool panel creates a new document that contains the line section.

The Tool chart section of the Tool Results panel displays a preview chart of the selected line.

The Tool status section of the Tool Results panel displays the calculated "Length" and "DeltaZ" of the selected line. For more information on the data in the Tool status section (see *Tool status section* (page 237)).

Cut Out Area
Creates a new measurement document containing a subsection of an existing measurement.

One corner of the area is defined by the mouse cursor position where the left mouse button is clicked, the opposite corner by the position where the button is released. When the mouse is not moved between clicking and releasing, an area is defined that has a size of 33% of the current measurement, and is centered on the clicked location.



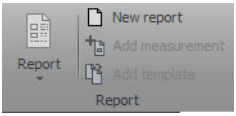
Once an area is defined, it can be resized by dragging one of its corners, and moved as a whole by dragging its center point.

Pressing the "Shift" key while dragging a corner defines a non-square (i.e. rectangular) area.

Double-clicking the graph, or clicking the "Cut out area" button in the Tool Results panel creates a new measurement document that contains the selected area.

The Tool status section of the Tool Results panel displays the calculated "Size" or "Width" and "Height" of the selected area. For more information on the data in the Tool status section (see *Tool status section* (page 237)).

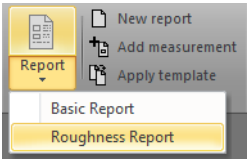
13.5.6: Report Group



The Nanosurf Report software offers a powerful and extensive set of analysis functions. Complex analyses can be created interactively, and then displayed and printed in visually appealing reports. These reports can then be used as templates to consistently apply the same analysis to other measurements.

Report
The "Report" button starts the Report software (if installed) from within the SPM Control Software:

When a measurement is opened by the Report software, it will import all measurement channels that are displayed in the current measurement document. By default, a Basic Report is generated. Other Report styles can be chosen from the "Report" button's drop-down-menu:



This drop-down menu lists templates stored in a template folder. The Menu Item's name is equal to the template name without the extension (*.mnt) and is sorted alphabetically. This standard directory is configured by the Report Template File path (see *Reporting* (page 247)).

IMPORTANT

After a fresh installation of the Report software, the Report software has to be run at least one time before you can automatically start it from the SPM Control Software. To run the Report software for the first time, select it from the Windows "Start" menu.

New Report
An empty report is opened.

Add Measurement
The currently active measurement is added to the currently opened report.

Apply Template
Opens a dialog that allows you to select a template that is applied to the currently active measurement. If selected, a menu item the template is applied to the current selected measurement Document.

IMPORTANT

If you do not save the measurement in the control software, but only save the report, the data in measurement channels that were not displayed is lost.

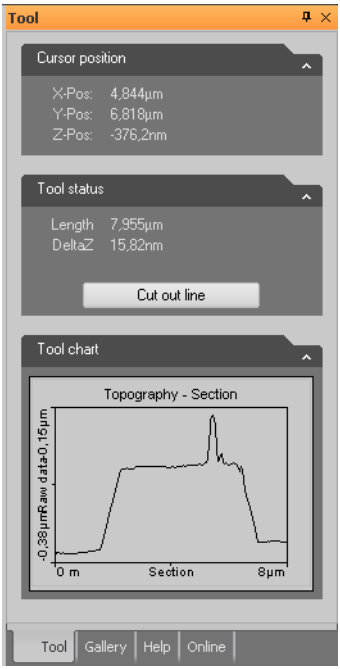
IMPORTANT

A measurement document should only display those channels that are used in a template. When a template is applied to a measurement document that displays different, or a different number of measurement channels than the template uses, the results may not be correct.

13.5.7: Scripting group

Please refer to *Section 10.4.2: Scripting group* (page 157).

13.6: Tool panel



The Tool panel of the Info pane displays varying information, which depends on the tool currently selected in the Analysis tab.

Cursor Position section

This section is always visible. It displays the mouse cursor position in the physical units of the selected chart.

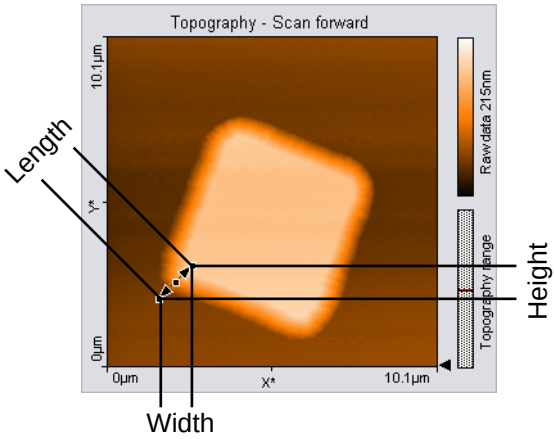
Tool status section

This sections appears when a tool is being used. It displays the evaluation result of the currently active tool.

The tools that require drawing a selection marker to define the evaluation have some common parameters that are described here. The other parameters are described in the sections that describe the respective tool (see above).

Length
The length of the selection marker in the plane of the chart. "Length" is related to the evaluation results "Width" and "Height" (see below) according to the formula:

$$Length = \sqrt{Width^2 + Height^2}$$



In a Color map chart, length is calculated in the XY-Plane. In a Line graph chart, length is calculated in the XZ-Plane.

"Length" is not displayed when "Width" and "Height" are of different physical units (e.g. in Amplitude Spectroscopy, where the X-Axis is given in [m] and the Z-Axis in [V]).

Width, Height
The "Width" and "Height" of the measurement tool in the chart, calculated in the chart plane.

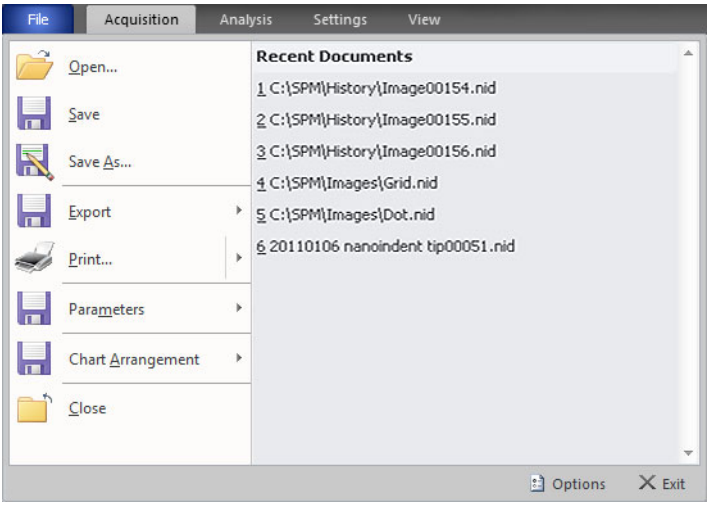
DeltaZ
The difference between the "Z-Pos" values at both ends of the selection marker.

In a Color map chart, "DeltaZ" is the difference in the (filtered) sample height between the start and the end point.

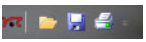
IMPORTANT

The calculated values of "Length", "Width" and "Height" only depend on the cursor positions, they do not depend on the displayed data values.

13.7: File menu



The File menu is accessed by clicking the File tab at the left side of the Ribbon. It provides access to software related settings and options (see *Section 14.1.1: Options dialog* (page 243)), but also to basic file operations such as such as opening, storing and printing of measurements (explained below). The latter functions can also be performed using the Quick Access toolbar, in which these commands are present by default:



Open

Launches a system "File open" dialog for opening Nanosurf ".nid" or ".ezd" (Easyscan 1) files. It is possible to select more than one file at the same time by using the "Shift" and/or "Ctrl" keys.

Selected files will open in document windows, which contains a chart area and a data info panel. There is no Imaging toolbar like there is for ongoing measurements in the Imaging window. You can however still customize the charts through a context menu, which opens through a right-click. The data info Panel displays all significant parameters were used for the measurement. For more information on Measurement document functionality, see *Section 13.1: Introduction*.

Save / Save as...

Save a measurement document in Nanosurf image data format (file extension ".nid"). The same dialog is opened for both menu items.

Close

Closes the currently active document, but not the SPM control software. If you have unsaved data in the current document, you will be asked to save it.

Export

Exports either the active chart or the whole active measurement document for use in other programs or image-processing software. Available data types for documents are tagged image file format (.tif), portable network graphics (.png), Windows bitmap (.bmp), 16 bit data file (.dat), and plot file (.plt). For Charts, additional available data types are comma separated z values (.csv), and (X,Y,Z)-points (.csv).

When the data is exported using the function "Export" >> "Current document as...", every Chart in the measurement document is stored in the export file consecutively. In the binary format, the blocks of data from each Chart are stored directly one behind the other. In the "ASCII" text format the blocks of data for each Chart are separated by two empty lines.

Tagged image file format (.tif), portable network graphics (.png), and Windows bitmap (.bmp)
All of these image file formats are suitable for inclusion of images in electronic documents, e.g. in Word, PowerPoint or image-processing software. The exact image as seen on the computer screen will be saved in the exported file (similar to a screenshot of the respective chart).

Data file 16Bit (.dat)
A binary data file that can be processed in data processing software. This "binary" data format only contains the measured data. The data is stored consecutively, line by line upwards, as 16-bit values (–32768 to +32767). Before being stored, the data is processed using the settings chosen in the Correction and Filter groups of the Analysis tab (see *Section 13.5: Analysis tab* for details).

Plotfile ASCII (.plt)
This is an "ASCII" text format which contains the measured data as well as a small header with a description of the scan. A plotfile can be used for detailed data analysis by various mathematical software packages such as MathLab, or for plotting by software such as GnuPlot. Before being stored, the data is processed using the settings chosen in the Correction and Filter groups of the Analysis tab (see *Section 13.5: Analysis tab* for details).

If "Line graph" is selected as "Display" in the "Chart bar", only the visualized lines will be stored. Each data point is stored as a pair of floating point numbers on a separate line. The number pairs are separated by a blank character (SPACE).

If any other chart type is selected, all measured values are stored. All values in a data line are stored on a separate line in the text file. An empty line is inserted after every data line. The data lines are stored from the bottom to the top. A small header at the beginning of the first data line contains the names of the channel and frame, as well as X-, Y-, and Z-ranges with their physical units.

Comma separated z values (.csv)
This format stores all the measured data in a chart, as a matrix of floating point numbers in ASCII format separated by a "comma" and "SPACE" character. This enables easy data exchange with commonly used spread sheet and database applications.

(X, Y, Z)-Points (.csv)
This format stores the coordinates of all measured points in a chart as a list of floating point number pairs. For Line graphs, only X and Z points are exported.

Print / Print preview...

Prints the currently selected measurement document together with the values shown in the Data Info panel.

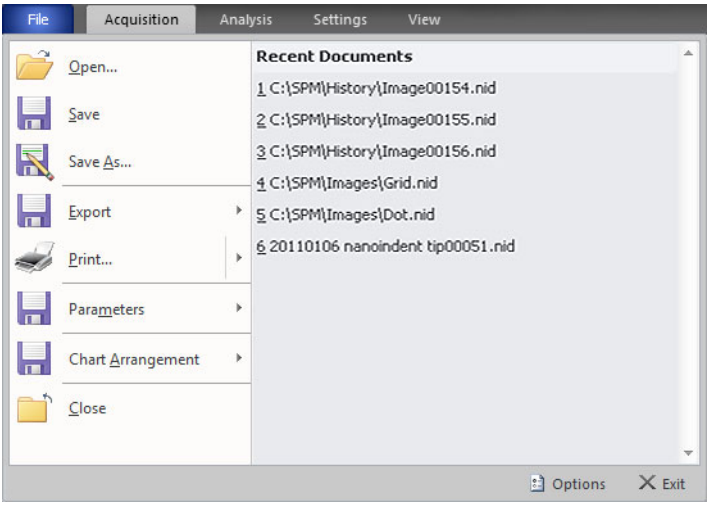
Exit

With exit you can close the SPM Control Software. If you exit the program while still having unsaved data, you will be asked to save it.

CHAPTER 14:

Options and settings

14.1: File menu



The File menu is accessed by clicking the File tab at the left side of the Ribbon. It provides access to basic file operations such as such as opening, storing and printing of measurements (explained in *Section 13.7: File menu* (page 238)), but also to some software related settings and options (explained below).

Parameters

All measurement parameters are stored in a configuration file with the extension ".par". When the SPM Control Software is started, default values are loaded from a file that is selected in the Controller Configuration dialog (*Section 14.7: Controller Configuration dialog*). Functions for storing and retrieving parameters are accessed via the application button.

Save

Saves the parameters to the currently selected parameter file. The name of this file is indicated in the status bar at the bottom of the main window.

Save as...

Saves the parameters under a new file name.

Load

Loads a previously saved parameter file.

Chart Arrangement

The chart arrangement of the Imaging and Spectroscopy windows is stored in a configuration file with the extension ".chart". When the SPM Control Software is started, a default arrangement is loaded from a file that is selected in the Controller Configuration dialog (*Section 14.7: Controller Configuration dialog*). Functions for storing and retrieving the chart arrangement are accessed via the application button.

Save
Saves the chart arrangement to the currently selected chart file. The name of this file is indicated in the status bar at the bottom of the main window.

Save as...
Saves the chart arrangement under a new file name.

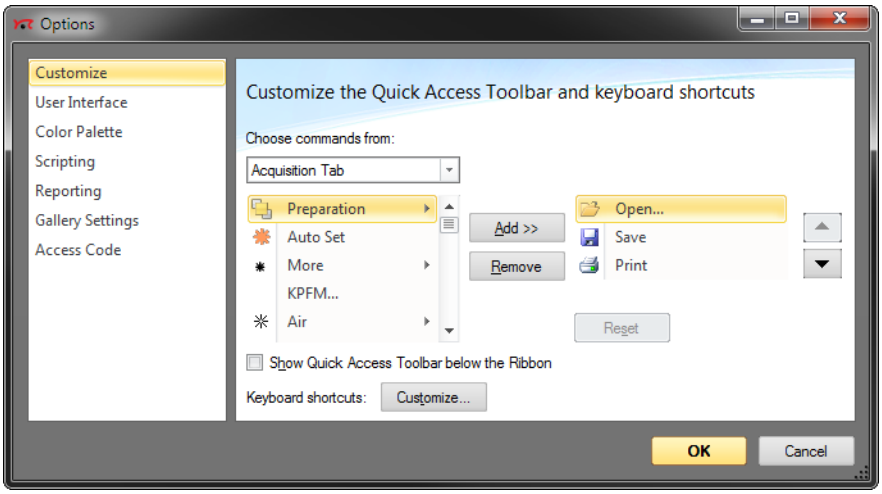
Load
Loads a previously saved chart file.

Options

The "Options" button opens the Options dialog (see *Section 14.1.1: Options dialog*), which configures various general control software settings.

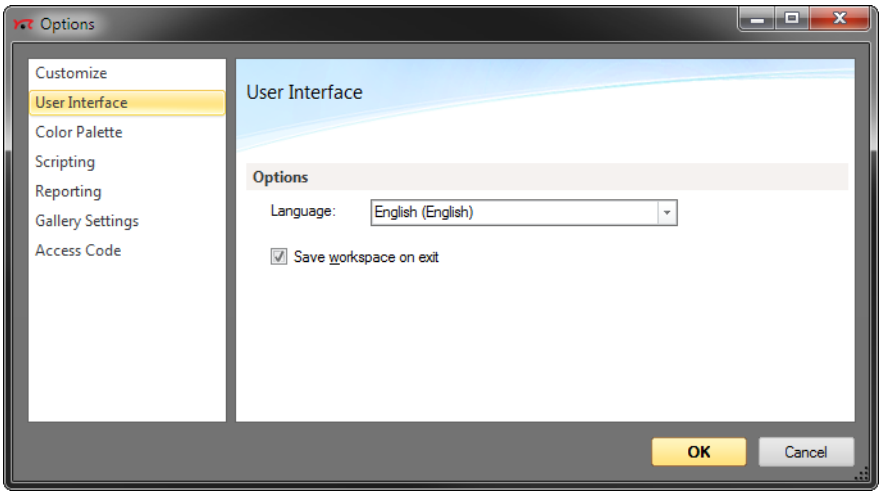
14.1.1: Options dialog

Customize



Allows changes to the content of the Quick Access toolbar (see *File menu* (page 242)). This process is very similar to that in the Microsoft Office applications and is therefore not explained in this manual. You are free to try it out and can always use the "Reset" button to reload standard settings.

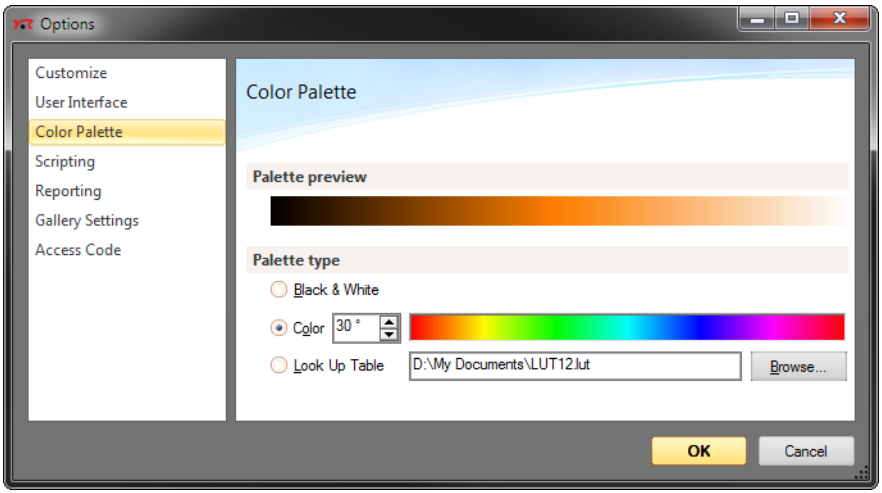
User Interface



Language
Specifies the SPM Control Software language.

Save workspace on exit
When checked, the workspace settings are automatically saved to the system registry when the control software is closed (see also *Parameters* and *Chart Arrangement* (page 243)).

Color Palette



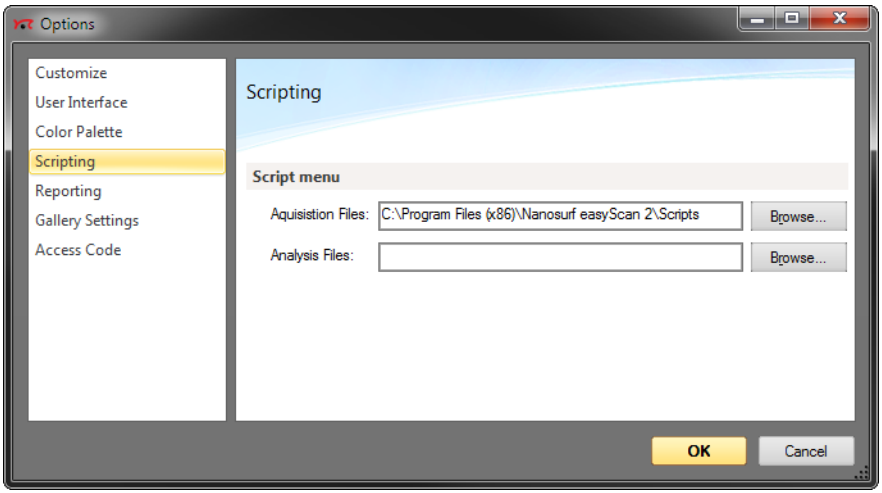
The color palette dialog is reached via the menu item “Options” >> “Config Color palette...”. The color palette is used to map the display range of the measured values to a color. Three different palette types are available:

– **Black&White**
  The color map is a linear gray scale.

– **Color**
  The color selection uses the HSB-color model where the color (H) is set in ° value. The color is selected by entering a number or by clicking a color in the color bar.

– **Look Up Table**
  A user definable palette (with max 256 color entries) can be selected. This palette is stored in a “.lut” file that contains an ASCII table with RGB color values. A different look up table can be selected by clicking the “Browse...” button.

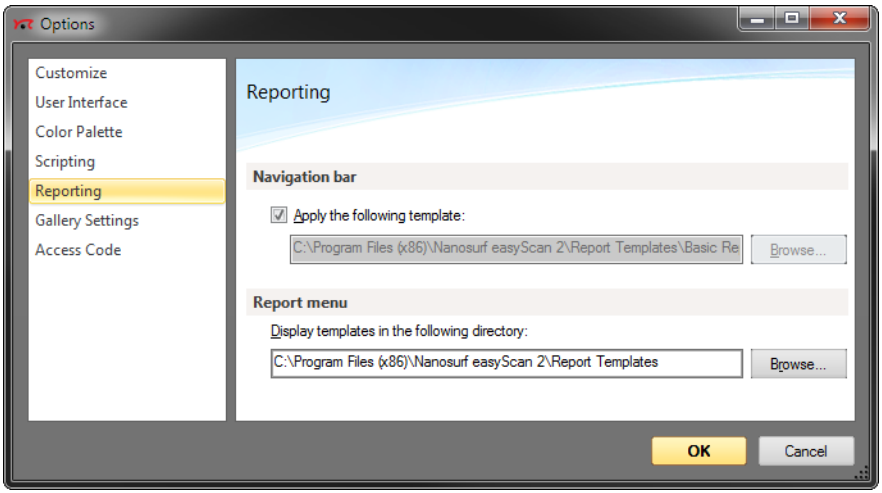
Scripting



Allows you to set the search paths for the Acquisition and Analysis scripts that are displayed in the Scripting group of the Acquisition tab and Analysis tab, respectively.

Scripts can be organized in subdirectories inside each of the “Script” directories, which are displayed as submenus in the control software. These submenus are displayed before individual scripts in the Script drop-down menu.

Reporting

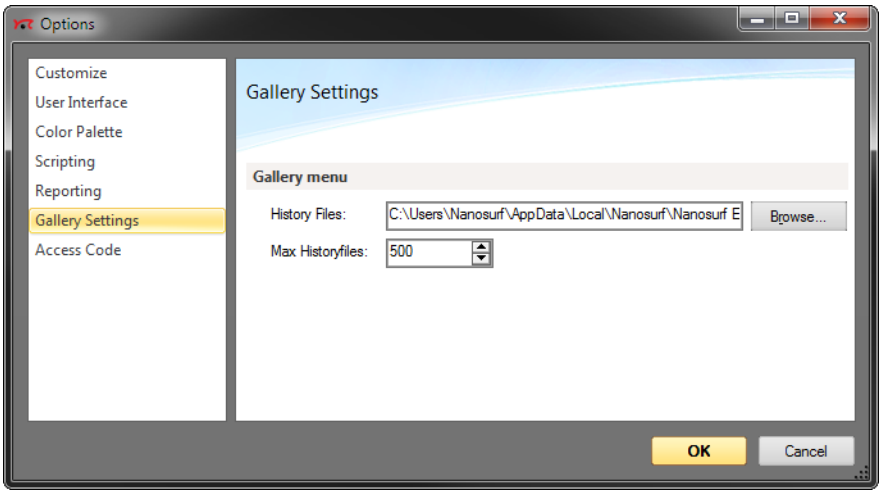


Used to configure the behavior of the “Report” button in the Report group of the Analysis tab.

Apply the following template
When enabled, automatically applies the template specified in the box below. You can search for a template using the “Browse” button.

Display templates in the following directory
As with the Stridulating paths (see *Scripting* (page 246)), the content of the specified directory is displayed as choices in the Report drop-down menu.

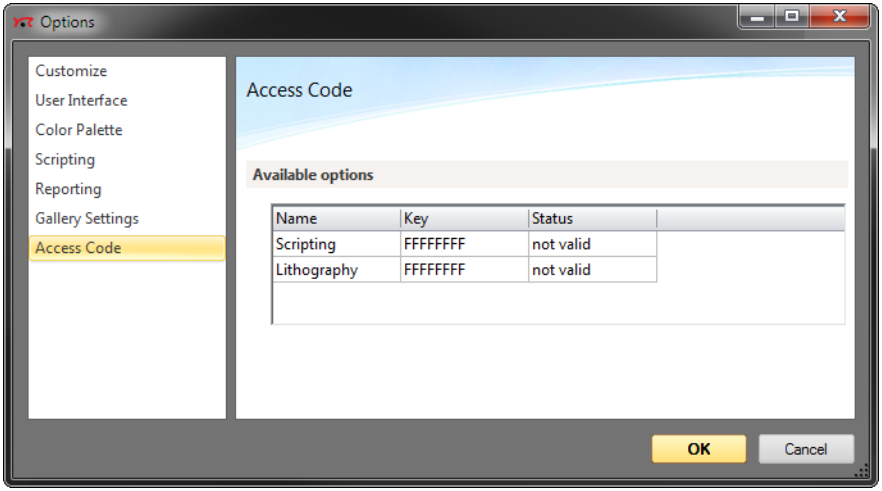
Gallery Settings



History files
Sets the directory where the temporarily (automatically) stored measurements (which are listed in the Gallery panel of the Info pane) are stored.

Max History Files
Sets the maximum number of files to keep in the above directory. When the maximum is reached, the oldest measurement is deleted from disk to allow the latest measurement to be saved.

Access Code

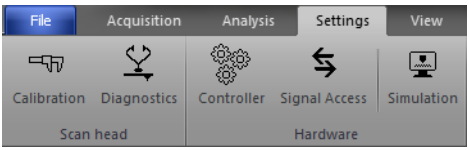


Used to enter the access code for software modules, such as the Scripting Interface and the Lithography Option..."

IMPORTANT

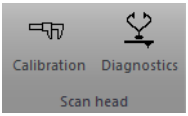
If you receive the warning "To change access codes you need Windows administrator rights", please restart the control software with the "Run as Administrator..." option from the Windows Explorer context menu.

14.2: Settings tab



Provides access to many hardware related settings.

14.2.1: Scan Head group



Calibration
This button opens the Scan Head Selector dialog to load, save or edit a scan head calibration file. For more details, see *Section 14.3: Scan Head Selector dialog* (page 251).

Diagnosis
This button opens the Scan Head Diagnosis dialog where the actual health state of the scan head can be seen. For more details, see *Section 14.6: Scan Head Diagnostics dialog* (page 255).

14.2.2: Hardware group

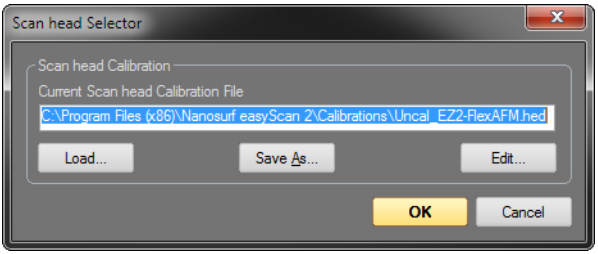
Controller
Opens the Controller Configuration dialog where different hardware related settings can be defined. It defines communications port, video driver settings, start up parameter and others. For more details, see *Section 14.7: Controller Configuration dialog* (page 257).

Signal Access
Opens the SPM Parameters dialog on the Signal Access page (see *Section 14.8.1: Signal Access page* (page 259)).

Simulation
Check or uncheck the Simulation button to enter or exit the control software's microscope simulation mode. Once the simulation mode is active, the status bar of the control software displays the text "Simulation". Otherwise, this field displays the text "Online".

In microscope simulation mode, many functions of the microscope are performed on a mathematically generated surface. Thus, software functionality and acquisition procedures can be practised without danger of harming the instrument.

14.3: Scan Head Selector dialog



The Scan Head Selector dialog is used to load, save or edit scan head calibration files. These files store all calibration values specific to a certain scan head. The Scan Head selector dialog is opened via the "Calibration" button in the Scan Head group of the Settings tab.

The configuration of each scan head is stored in a file with a filename that corresponds to the serial-number of that particular scan head and with the extension ".hed" (e.g. "10-11-584.hed" for an Easyscan 2 AFM scan head). The currently loaded scan head calibration file is displayed in the status bar.

Tip:

The specific scan head calibration file(s) for each customer is automatically copied and selected as default during the installation of the control software from the installation CD. It can be found in the "Calibrations" sub directory of your installation path.

IMPORTANT:

When you change a scan head, you have to load the correct configuration file too. If you do not, scan ranges and other important calibration settings are incorrect and the scan head may not operate properly.

Load...
Loads a different scan head calibration file.

Save as...
Saves the current scan head calibration file with a different name.

Edit...
Edit the currently loaded scan head calibration file using the Scan Head Calibration Editor dialog (see *Section 14.4: Scan Head Calibration Editor dialog*). Always save a backup copy of the original scan head calibration files by clicking 'Save As...' first.

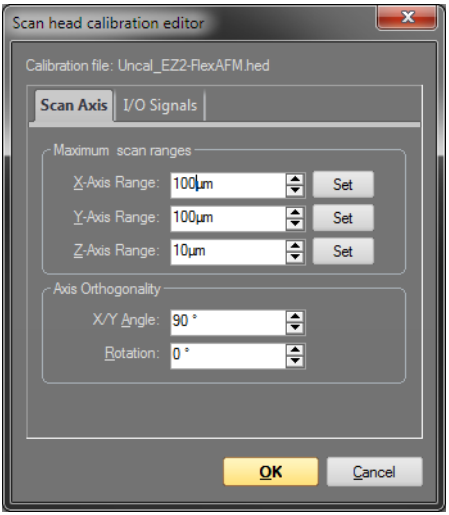
14.4: Scan Head Calibration Editor dialog

Through this dialog, the calibration of all standard Inputs and Outputs can be configured individually for a particular Scan Head. The configuration of the User Inputs and User Outputs is located in a different dialog (*Section 14.9: User Signal Editor dialog* (page 263).

CAUTION!

Changes to these settings should be performed with great care. False settings can lead to false interpretation of the data and incorrect operation of the controller.

14.4.1: Scan Axis



Maximum scan ranges

X/Y/Z-Axis Range
The calibration values of each of the scanner axes. The calibration values are given as the maximum motion range of the scanner (Overscan is set to 0% and X/Y Angle set to 90° and the Axis Orthogonality Rotation of 0° [or a multiply of 90°]).

Set
The "Set" buttons open the Scan Axis Correction dialog (see next section).

Axis Orthogonality

The X- and Y-Axes of the scanner are generally not perfectly orthogonal, and their orientation with respect to the AFM housing may vary. The controller corrects these errors by adding/subtracting some of the X scanner command signal to the Y scanner command signal and vice versa.

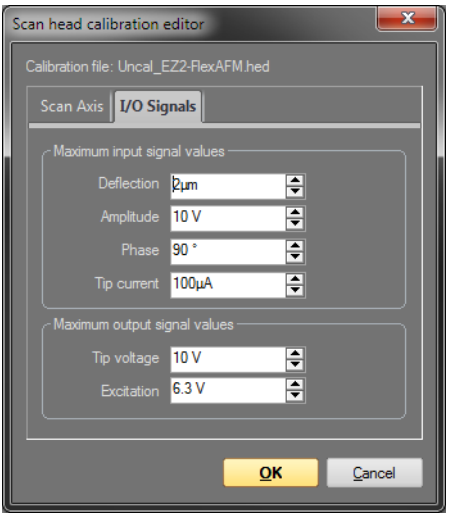
X/Y Angle
The angle between then the X- and Y-axis of the scanner hardware. The control software uses this value to correct the scan command signals such that the scan axes are orthogonal.

Rotation
The angle between the X-axis of the scanner and the X-axis of the microscope body (see *Figure 18-3: Scanner coordinate system* (page 286)). The control software uses this value to correct the scan command signals in such a way that the scan axis is parallel to the X-axis of the microscope body.

Tip

With this value, the alignment of the scanner's 0° Rotation and another system's coordinate system may be calibrated (e.g. images scanned with the LensAFM or Nanite AFM and optical images by external video cameras of optical profilometers or Nano-Indenters).

14.4.2: I/O Signals



Maximum input signal values

Deflection
The calibration of the cantilever deflection signal. This calibration value is used to convert the AFM Detector Signal or the STM preamplifier signal (both in Volts) to physical units.

IMPORTANT

This value has been pre-configured by Nanosurf for Static Force Mode operating mode with CONTR Cantilever and a Laser Spot at 225 µm. If other Cantilevers are used, or if the laser spot has been adjusted manually in case of a FlexAFM scan head, a recalibration of this value has to be performed. If not, the Set Point in [N] may be incorrect.

Amplitude (AFM only)
The calibration value of the cantilever vibration amplitude signal.

Phase (AFM only)
The calibration value of the cantilever vibration phase shift signal.

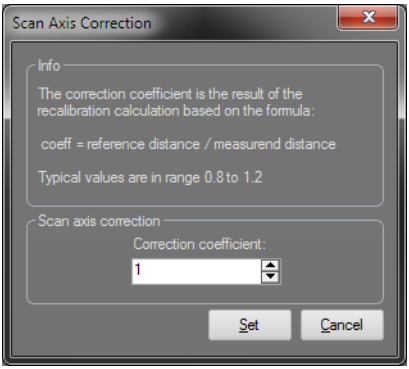
Tip current (AFM only)
The calibration value of the controllers internal Tip current preamplifier sensitivity.

Maximum output signal values

Tip Potential
The calibration value of the Tip voltage setting.

Excitation (AFM only)
The calibration value of the Amplitude of the signal that is used to excite the cantilever in dynamic force operating modes.

14.5: Scan Axis Correction dialog



This dialog can be used to correct the scan range by entering a correction factor based on a measured distance and a known real distance.

This correction factor could for example be determined by evaluating the height information in a measurement of a calibration grid with known properties.

Scan axis correction

Correction coefficient
The scan range is multiplied with this number when the “Set” button is clicked.

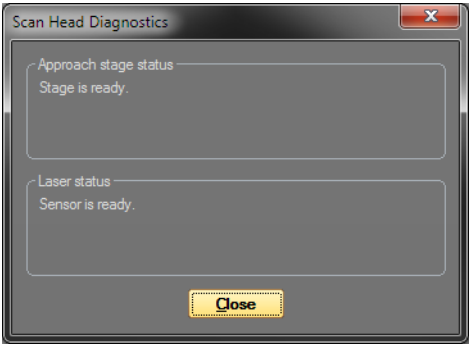
14.6: Scan Head Diagnostics dialog

The Scan Head Diagnostics dialog displays the current status of the scan head. It is opened by clicking the “Diagnostics” button in Scan Head group of the Settings tab.

Tip

The Scan Head Diagnostics dialog cannot be accessed once the tip has been approached to the sample. In this case, retract the tip first.

14.6.1: Dialog for AFM scan heads



Approach stage status

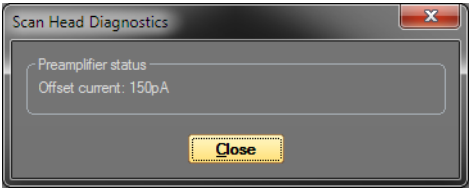
Status about the motorized approach stage is shown here.

Laser Status

Status about the laser / detector system is shown here.

If the Status light on the SPM controller is blinking red, more detailed information about the failure is displayed here (see also *Section 17.3.1: Probe Status light blinks red* (page 277)).

14.6.2: Dialog for STM scan head



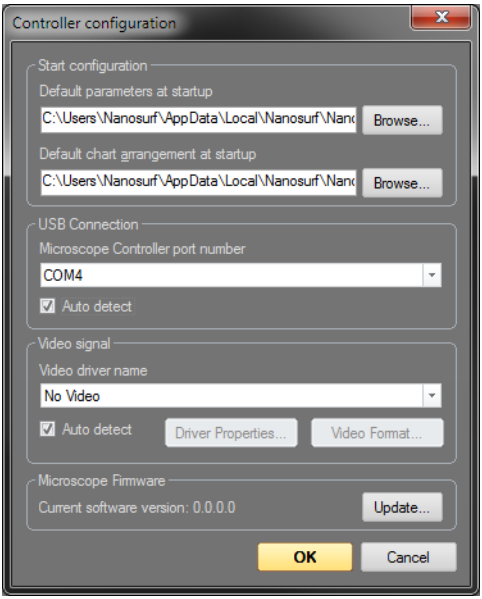
Information about the preamplifier that is present in the STM scan head is displayed here.

The offset current is a leakage current that is measured by the preamplifier when it is not in contact with the sample.

Note

The offset current is not only a measured value, but is also used as a compensating value during measurement. Therefore, even high values are not problematic for measuring at low tunnelling current.

14.7: Controller Configuration dialog



With this dialog some controller hardware related settings can be configured. On a correctly installed system, it should not be necessary to change these settings manually. The Controller configuration dialog is opened via the “Controller” button in the Hardware group of the Settings tab.

Start configuration

The parameter and chart arrangement files that are loaded when the SPM Control Software starts. Each Windows user has his/her own set of these two files a personal “Local Settings” directory. Therefore, each windows user can configure the control software to his/her own personal preferences without any consequences for other users.

USB Connection

The SPM controller uses a virtual serial port that is connected to the USB port. The number of this virtual serial port should be the same as the one shown in your the windows device manager dialog. Activate "Auto detect" to let the control software search for the right COM port at each program start. This is highly recommended, because Windows assigns individual COM port numbers to different USB connectors. With auto detect, you will be able to plug in the USB cable to different ports.

Tip

If the port number is set to "No Controller (Simulation only)" and "Auto Detect" is switched off, the control software will always start in Simulation mode. This could be useful if the software will be used mainly for analysis and is installed on a PC without microscope hardware.

Video Signal

Allows the selection of the video device driver used to handle the video camera of the SPM controller or scan head. Activate "Auto detect" to let the control software search for the right device driver. The control software then automatically selects the correct device driver for different scan heads if available. If a video device is found, the Video Panel will automatically be present in the Info pane.

Select "No video" in the list if you wish to completely suppress the video display.

Microscope Firmware

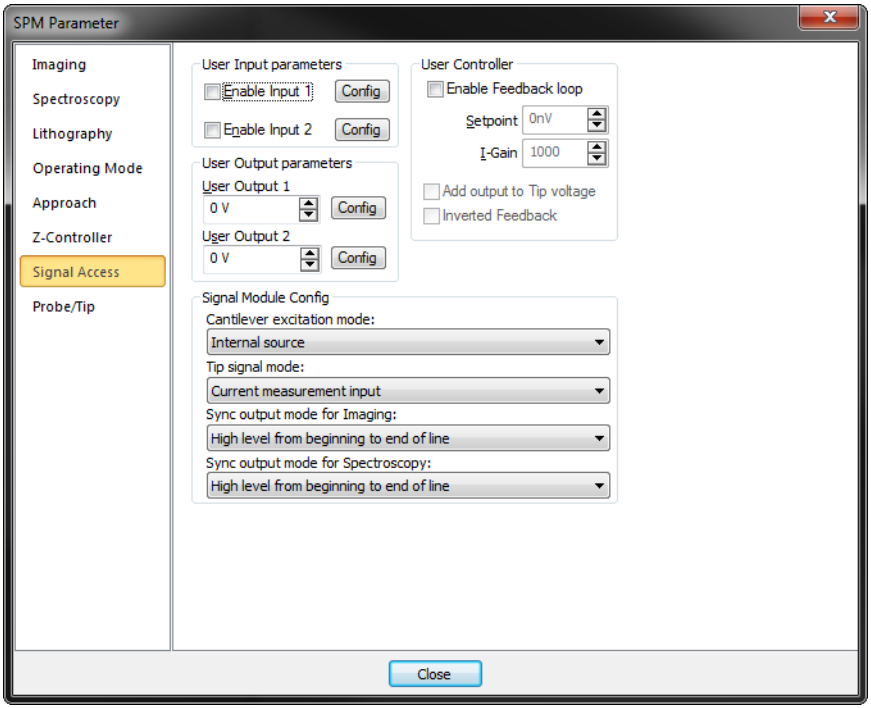
Here the currently used firmware version of the controller is shown.

In case of a standard software update (downloaded from the Nanosurf homepage) manual update of new firmware is normally not necessary since it is performed automatically at the start of the updated SPM Control Software. Automatic firmware update is always performed each time a different (older or newer!) software version is started since last time.

Click the "Update" button to install individual firmware updates you received from Nanosurf support.

14.8: SPM Parameters dialog

14.8.1: Signal Access page



When the Signal Module A is installed, the Signal Access page allows several parameters to be configured.

User Input Parameter

Enable User Input 1 / 2
When checked, the data from the selected User Input(s) is measured and stored during all acquisition processes (e.g imaging or spectroscopy). See also *Section 19.4.2: Signal Module A* (page 294).

Config
The "Config" button opens the User Signal Editor dialog (see *Section 14.9: User Signal Editor dialog* (page 263)) to set the signal's name, range and unit.

User Output Parameter

User Output 1 / 2
Sets the static output value of the selected user output(s).

Config
The "Config" button opens the User Signal Editor dialog (see *Section 14.9: User Signal Editor dialog* (page 263)) to set the signal's name, range and unit.

User Controller

Enable Feedback loop
Activates an auxiliary feedback loop controller. This feedback loop controller uses the User Input 1 as its signal input and drives the User Output 1 with it control value. It can be used for custom measurements in all modes; Static as well as Dynamic mode (See "Help panel" >> "AppNotes" >> "AN00031 — KPFM Operating Mode").

Setpoint
Defines the Setpoint of the feedback controller. The controller keeps the User Input Signal 1 at this value.

I-Gain
Defines the I-Gain of the feedback controller.

Add output to Tip voltage
When checked, adds the feedback controller's output voltage to the Tip voltage output.

Inverted Feedback
Inverts the direction of the feedback response. Depending on the experiment to be controlled, the feedback may have to increase or decrease its output value to force the User Input signal to reach the Set Point.

Tip

If the overall gain of the experimental setup from its input to its output is positive, feedback has to be non-inverted. If it has a negative gain, feedback has to be inverted.

Signal Module Config

Cantilever Excitation Mode
The following options are available:

- **Internal source**
  Cantilever excitation is controlled by the Easyscan 2 controller itself.
- **External source**
  Cantilever excitation is controlled by an external source.

Tip Signal Mode

The following options are available:

– **Current measurement input**
  Sets the tip signal to the input current measurement level.
– **Voltage source output**
  Sets the tip signal to the measured output voltage.
– **Direct feed through with "Tip Voltage" Input-BNC**
  Establishes a direct connection between the "Tip-Voltage" Input-BNC connector and the cantilever.

These options are summarized in *Figure 14-1: Tip Signal Mode schematic*.

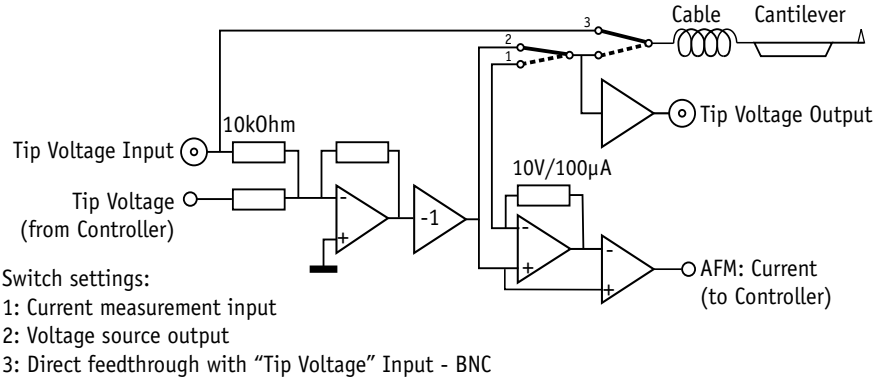
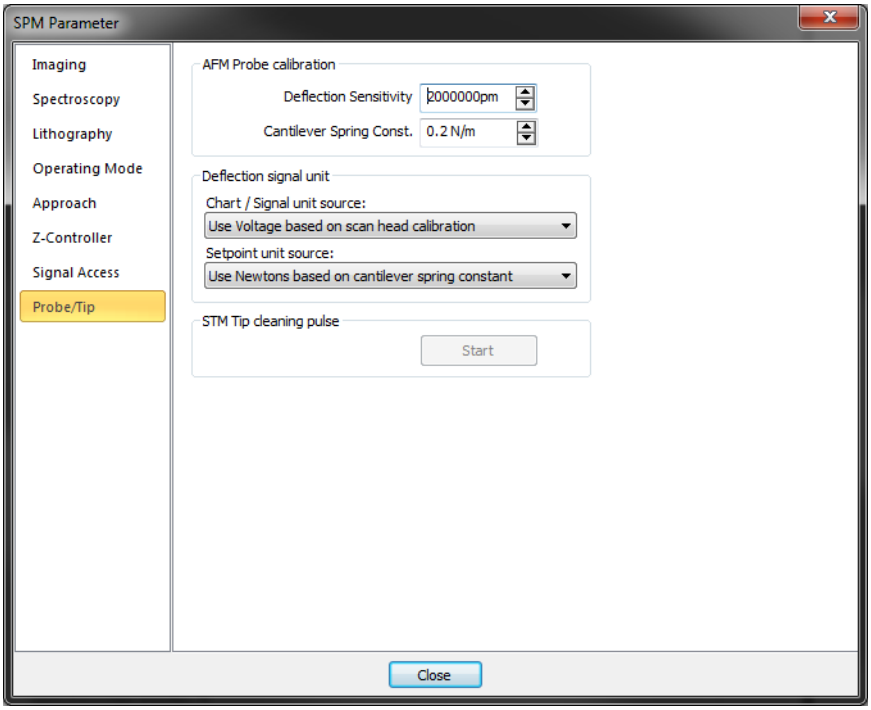


Figure 14-1: Tip Signal Mode schematic. Describes the electronics behind the three Tip Signal modes.

Sync output mode for Imaging / Spectroscopy

Allows configuration of the "Sync" output that can be used to synchronize external equipment with the SPM controller. Different options can be used for the Imaging and Spectroscopy modes.

14.8.2: Probe/Tip page



When the Signal Module A is installed, the Signal Access Page allows several parameters to be configured.

AFM Probe Calibration

Deflection Sensitivity
This value defines the scan head's deflection sensitivity as used by the SPM control software for internal calculations. Its default value is taken from the deflection value stored in the scan head calibration file. For each new calibration file loaded, this value will be set according to the new calibration file's deflection value. This default value may be not precise enough for very accurate force measurements. In such cases, you may overwrite it by a value as measured from a Force–Distance spectroscopy curve.

Cantilever Spring Const.
This value defines the spring constant of the selected cantilever, as used by the SPM control software for internal calculations. Its default value is taken from the currently selected

cantilever's database entry (see *Section 8.12: Cantilever Browser dialog* (page 117)). Each time a new cantilever is selected, this value is overwritten to the default value of the newly selected cantilever. This default value may be not precise enough for very accurate force measurements. In such cases, you may overwrite it by a measured value (e.g. a calculated spring constant, based on a mechanical cantilever model and the resonance of the cantilever).

Deflection signal unit

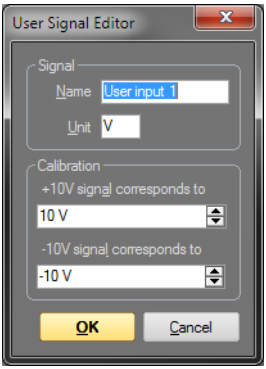
For all Static Force operating modes, it is possible to select different deflection signal units to be used for display in Charts/Signal values, and as used for the Setpoint. Three choices are available for each:

- **Use meters based on head calibration**
  The deflection of the cantilever is displayed in meters. This is the default setting for Chart.
- **Use Newtons based on mounted cantilever's spring constant**
  The deflection of the cantilever is displayed in Newtons in all charts. This is particularly useful for recording Force–Distance curves with the Spectroscopy Window. This is the default settings for SetPoint.
- **Use meters based on head calibration**
  The deflection of the cantilever is displayed in Volt.

STM Tip Cleaning Pulse

Start
Applies a short voltage pulse to the STM tip to remove material picked up by the tip during measurements. The voltage pulse is approximately 5 V in height and 100 ms in duration. It can be used to clean a dirty STM tip.

14.9: User Signal Editor dialog



The User Signal Editor dialog is used for editing the calibration of the User Input/Output signals. The settings made in this dialog are stored in the active Scan Head calibration file.

Name
The name of the user signal. The entered name is used throughout the control software.

Unit
The base unit of the physical signal, without prefix (i.e. 'm', not 'nm' or 'µm').

Calibration
The physical signal values that correspond to the maximum and minimum signal voltages should be entered here. Prefixes can be used.

CHAPTER 15:

Quick reference

Quick reference

PART C:

APPENDICES

CHAPTER 16:

Maintenance

16.1: Introduction

To ensure fault-free operation of the microscope, the maintenance instructions below have to be observed.

16.2: The FlexAFM scan head

It is important to keep the open parts of the scan head clean. Therefore, always store the scan head in a dust-free and dry environment when it is not in use. If exposed to moisture (high humidity) over a prolonged period, corrosion will occur.

16.3: The cantilever holder

The cantilever holder should be cleaned after each use in liquid environment. If it should still become dirty over time, use the following procedure to clean it:

1. Use a mild dish soap to clean the cantilever chip and SureAlign optics on the outside of the cantilever holder.

   Avoid wetting the inside of the cantilever holder, unless the optical components are dirty on the inside as well. In this case:

   A. Use a slightly wettened cotton bud to clean dirty parts on the inside of the cantilever holder.

   B. Use a fresh cotton bud to dry the clean surfaces.

   A cotton bud may be used on the outside of the cantilever holder as well to assist in removing sticky residues.

2. Wash the outside of the cantilever holder with water.

3. Wash the outside of the cantilever holder with 70% ethanol or 100% iso-propanol (sometimes written as 2-propanol).

   Both solvents can remove most non-water-soluble residues, such as the ones deposited by air dusters (if these are not used properly). The 70% ethanol treatment is also a good way to sterilize the cantilever holder when it has been used with liquids and biological samples (e.g. living microorganisms).

4. Air-dry the cantilever holder and store it dust-free.

16.4: The Easyscan 2 controller

To clean the case and the controls of the controller:

- Use a soft cloth, lightly moistened with a mild detergent solution. Do not use any abrasive pads or solvents like alcohol or spirits.

CHAPTER 17:

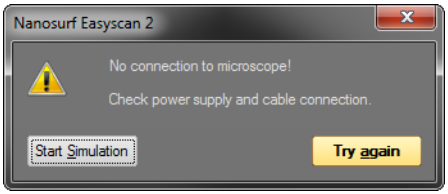
Problems and solutions

17.1: Introduction

The problems described here can occur during normal operation of the microscope. If the suggested course of action does not solve the problem, or the problem is not described here, refer to *Section 17.4: Nanosurf support* (page 279).

17.2: Software and driver problems

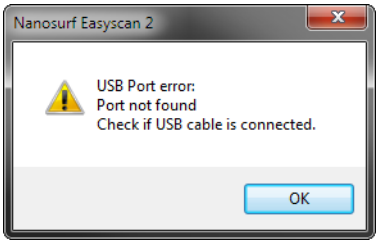
17.2.1: No connection to microscope



This error message appears when the Easyscan 2 software is waiting for an answer from the controller. Most likely, the Easyscan 2 is not connected to the mains power, or it is not turned on. In this case the status lights on the top of the controller are off. To fix this problem:

➔ Check the connections and the power switch.

17.2.2: USB Port error



The USB serial converter is not available. The USB cable is not properly connected. In this case the USB power light on the Easyscan 2 controller rear panel) does not light up (*Figure 1-4: The Easyscan 2 controller* (page 21)). To fix this problem:

1. Check if the a second copy of the Easyscan 2 is already running and occupying the USB port.
2. Check that the USB cable is properly connected.

If this does not solve the problem, check if there is a driver problem with the USB Serial port/USB Serial converter drivers, as described in the next section.

17.2.3: Driver problems

If you have trouble connecting to the controller, or if the video image in the positioning window is not available, it is possible that one of the drivers of your instrument is causing problems, for example because the installation did not work, or the installation of some other hardware is in conflict with the drivers of the Easyscan 2. In order to solve driver problems:

1. Check for driver updates on the Nanosurf Support web site.
2. Insert the installation CD for your instrument.
3. Log in with Administrator privileges.

The device manager can then be opened to view and correct any driver problems:

1. Open the windows menu “Start” >> “Control Panel”.
   The control panel now opens.
2. Select “Large icons” or “Small icons” if “View by” is set to “Categories”.
3. Double-click the “Device Manager” icon.
   The device manager now opens.

When the device manager opens and your controller is connected to your computer, you may see the drivers shown in *Figure 17-1: Device manager* (information may vary depending on the configuration of your system).

If there are problems with any of these drivers, or a wrong driver is installed, you can try to do the following to fix this:

1. Double click on the driver.
   Properties dialog for the device now opens.
2. Select the “Driver”-tab.
3. Click the “Update Driver”-button
   Windows will now ask you where to look for the driver.
4. Instruct windows to manually search for the driver files on the Installation CD.

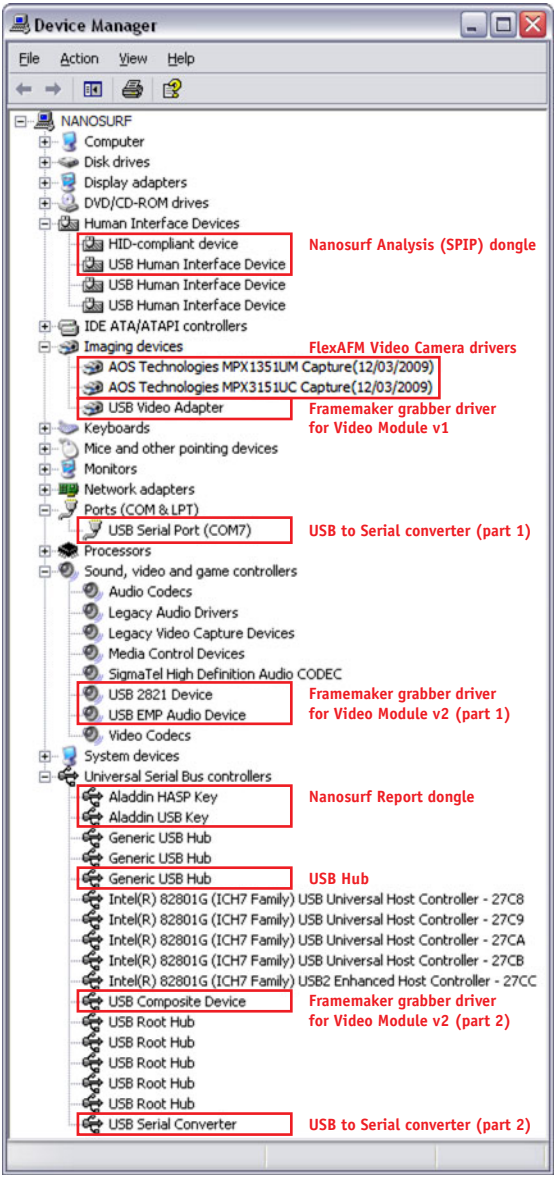


Figure 17-1: Device manager. The drivers that may be installed on your system when your controller is connected to the computer.

17.3: AFM measurement problems

17.3.1: Probe Status light blinks red

This light will blink red when an insufficient amount of light reaches the detector of the cantilever deflection detection system. This can either be due to a misaligned cantilever chip or to an air bubble being trapped in the optical path during liquid measurements.

To remove an air bubble during liquid measurements:

1. In the Approach group of the Acquisition tab, click the "Home" button to fully retract the cantilever.
2. Lower the sample platform of the sample stage by turning the manual Z-axis adjustment knob counterclockwise.
3. Repeat the approach as described in *Section 4.4: Approaching the sample* (page 48).

   Please note that the Probe Status light will temporarily start blinking when the cantilever first comes into contact with liquid, but this should go away when immersing the cantilever further. If it doesn't go away, there most likely is trapped air between the cantilever and the optical parts of the cantilever holder. To eliminate this problem:

   A. Finish measuring as described in *Section 6.1: Finishing scanning* (page 70).
   B. Extensively clean the Cantilever holder, as described in *Section 16.3: The cantilever holder* (page 270).
   C. Repeat the approach procedure.

To check for a misaligned cantilever:

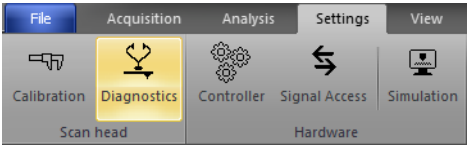
1. Remove the Scan Head from the stage.
2. Make sure that the cantilever is lying perfectly in the alignment chip (for details, see *Figure 3-5: Cantilever Alignment* (page 37)).

   If the cantilever is not well-aligned, there may be dust between the cantilever and alignment chip. To correct this:

   A. Remove the cantilever as described in *Section 3.3: Installing the cantilever* (page 33).
   B. Blow away dust from the alignment chip and the back side of the cantilever using dry, oil-free air. Mount the cantilever again.

For further details on the status of the laser detection system, open the Scan Head Diagnostics dialog:

1. In the Scan Head group of the Settings tab, click the "Diagnostics" button:



The Scan Head Diagnostics dialog now opens.

❷ Check the laser efficiency and position on the photodiode detector.

In some rare cases, the blinking of the Probe Status light may be caused by light from external sources reaching the photodiode detector. If this is the case:

➔ Turn off/down the external light source, or shield the scan head from its influence.

17.3.2: Automatic final approach fails

If the automatic approach fails, the Setpoint may either be too high, or the distance between tip and sample is larger than the maximum automatic approach range of the scan head. To solve these issues, try the procedures below (if necessary, try each and/or both procedures repeatedly until the automatic final approach is successful).

To check for a low Setpoint, repeat the approach as follows:

❶ In the Approach group of the Acquisition tab, click the "Home" button to fully retract the cantilever.

❷ Decrease the Setpoint by 5-10% (see *Z-Controller section* (page 153)) and *Section 4.2.1: Entering and changing parameter values* (page 47) for details on how to do this).

❸ Repeat the automatic final approach as described in *Section 4.4.3: Automatic final approach* (page 52).

To check for a large tip–sample distance, repeat the approach as follows:

❶ In the Approach group of the Acquisition tab, click the "Home" button to fully retract the cantilever.

❷ While watching the side view of the cantilever, manually approach a bit further by turning the Leveling Screws counterclockwise (see *Section 4.4.1: Manual coarse approach using the FlexAFM Sample Stage* (page 49)).

❸ Repeat the automatic final approach as described in *Section 4.4.3: Automatic final approach* (page 52).

If both of these procedures do not solve the problem, check the status of the cantilever deflection detection system (*Section 14.6: Scan Head Diagnostics dialog* (page 255)) or try installing another cantilever.

17.3.3: Image quality suddenly deteriorates

Tip picks up material

When a scan line suddenly starts reproducing badly, the tip may have picked up some particles.

To get rid of these particles, follow the procedure below until the image quality improves:

1. Continue measuring for a while (1–2 images), as the tip may eventually lose these particles again.
2. In the Approach group of the Acquisition tab, click the "Withdraw" button to retract the cantilever, and then perform a new approach.
3. Try to induce changes in the tip end:
   - A. While measuring, increase the force "Setpoint", or decrease the amplitude "Setpoint" in the Z-Controller section of the Imaging window.
   - B. Restore the Setpoint to its old value when the contrast improves, or if nothing happens after scanning several lines.
4. Change the cantilever if no improvement occurs after following the steps above.

Setpoint drift

When part of the scan line in the Line graph is drawn red, the tip has moved to its maximum or minimum Z-position. This should also be visible in the range display on the right hand side of the graph. The tip will move to its maximum Z-position when it has lost contact with the sample. To correct this:

1. In the Static Force based modes, increase the force Setpoint, in the Dynamic Force based modes, reduce the amplitude Setpoint.
2. If this does not help, retract and re-approach the tip.

17.4: Nanosurf support

17.4.1: Self help

The fastest way to solve a problem is often to solve it yourself. If the previously suggested actions did not help, or the problem is not described here, refer to the Nanosurf support pages:

1. Open *www.nanosurf.com*.
2. Click on "Support".

❸ Enter the login and password combination that you received upon registering.

❹ Select the Easyscan 2 link.

❺ If the problem is software related, try to upgrade to the latest version and/or read the "SPM Software Version History" to see if the problem was solved. For the solution to other problems, refer to the Frequently Asked Questions (FAQ).

If your instrument has not been registered yet, you will first have to register to receive a password.

17.4.2: Assistance

If the standard solutions are not sufficient, contact your local distributor for help. In order to resolve the problem as fast as possible, please provide as much information as possible, such as:

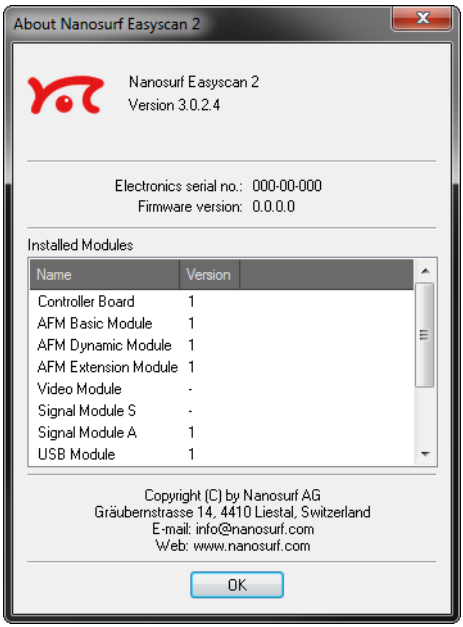
- A detailed description of what happened before the problem occurred. For example: "When I click the 'Approach' button, then quickly click abort, the controller will not react to anything I do anymore. This only happens when measuring in Dynamic Force Mode."
- If an error message was displayed: The exact text of the message, or at least the start of the message.
- The serial number of your scan head and/or controller.
- A description of the computer hardware and software on which the control software is running: computer brand, type (laptop or desktop), operating system, software version etc.
- Original Nanosurf image data (.nid) files that show the problem, rather than bitmap screen shots, because these files contain all the settings that were used to make them.
- Parameter (.par) files with the instrument settings that were used when the problem occurred.
- Script files, if the problem occurs during the operation of a script.

IMPORANT

Sending ".vbs" scripts by e-mail often does not work, because these files are usually blocked as a security measure. To successfully e-mail a script, you may either:

- Add the script text to the body of the e-mail.
- Change the extension of the script file to ".txt" and attach it to the e-mail.
- Compress the script file to a ".zip" archive and attach it to the e-mail.

17.5: About dialog



The About dialog displays information that may be useful for diagnostics when you have problems with your instrument. The About dialog is opened by clicking the “Information” button on the upper right corner of the program window, just below the “close window” button:

The About dialog contains the following information:

- The version number of the control software.
- The serial number of the controller (when the microscope simulation is active, the serial number “0xx-00-000” is displayed).
- The version number of the firmware that is running on the controller.
- The version number of all modules built into the controller.
- The version number of all installed software options.
- Contact information for getting more support.

CHAPTER 18:

AFM theory

18.1: Scanning probe microscopy

The FlexAFM is an atomic force microscope, which is part of the family of scanning probe microscopes. With the first scanning probe microscope, the scanning tunneling microscope (STM), it became possible to look into the fascinating world of atoms. The STM was developed by Gerd Binnig and Heinrich Rohrer in the early '80s at the IBM research laboratory in Rüschlikon, Switzerland. For this revolutionary innovation, Binnig and Rohrer were awarded the Nobel prize in Physics in 1986.

However, the STM technique is restricted to electrically conducting surfaces. An extension of this technique, called the Atomic Force Microscopy (AFM), was developed by Gerd Binnig, Calvin Quate and Christoph Gerber. The AFM also allowed insulating materials to be analyzed. Both the AFM and the STM microscopy techniques work without optical focusing elements. Instead, a small sharp probing tip is scanned very closely across the sample surface. The distance between the tip and the sample surface is so small that atomic-range forces act between them. In an AFM, a tip is attached to the end of a cantilever in order to measure these forces. The force acting on the tip can then be determined by detecting the deflection of this cantilever (see *Figure 18-1: Cantilever*).

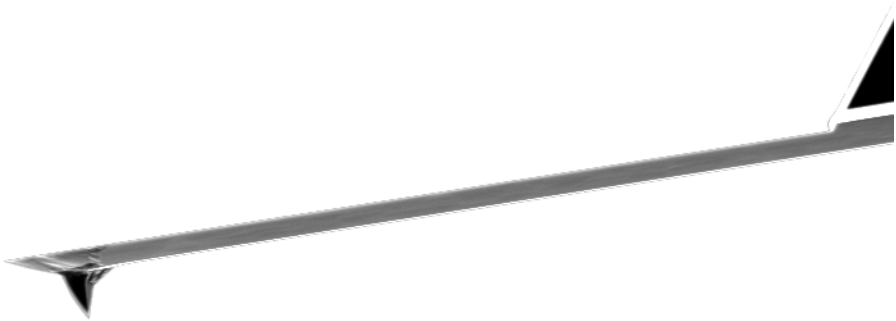


Figure 18-1: Cantilever. 228 µm long micro-fabricated silicon cantilever with integrated tip.

The measurement of the cantilever deflection can be used to control the tip–surface distance on an atomic scale. Thus, enormous resolution can be achieved, so that even the atomic arrangement of surfaces can be probed. This measurement is a so-called static operating mode, in which the static deflection of the cantilever is used. Generally, the forces acting on the tip will cause it to snap onto the sample, which result in an effective, nanometer-range flattening of the tip, and friction and stiction between the tip and the sample.

To circumvent the aforementioned problems, the so-called Dynamic force microscopy modes can be used, as was pointed out by the AFM inventors. In these modes, the cantilever vibrates during the operation. In the dynamic modes, changes in the free

resonance frequency and the damping of the cantilever vibration caused by the forces between the tip and the cantilever can be measured and used to regulate the tip–sample distance.

To achieve atomic resolution, ultra-clean and flat surfaces prepared in highly sophisticated vacuum systems are needed. Nevertheless, measurements in air can give useful results for many technically relevant surfaces. In this manual, the use of the dynamic modes in air on such surfaces is described.

18.2: The FlexAFM

The FlexAFM is an AFM that can be used in both static (SPM S50 and SPM S200 controller) and dynamic operating modes (SPM S200 controller only). The AFM cantilever is a microfabricated cantilever with an integrated tip mounted on a cantilever holder chip.

When the sensor tip comes in contact with the sample, a repulsive force that increases with decreasing tip–sample distance acts on it. In the static force operating mode, the bend of the cantilever, due to the force acting on its tip, is measured using a cantilever deflection detection system.

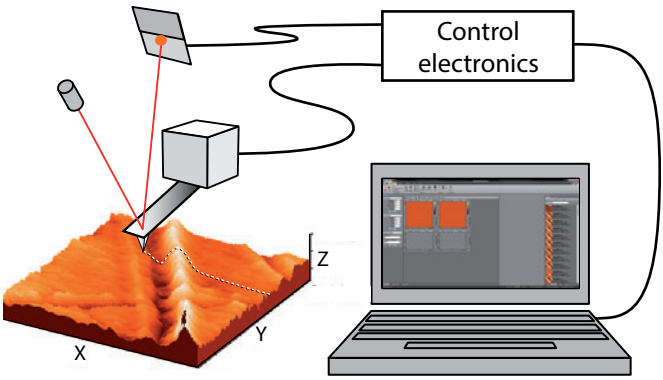


Figure 18-2: SPM system. Cantilever with deflection detection system scanning the sample. The sample is visualized on a computer with installed scan software, which also directs the scan itself.

In dynamic operating modes, the cantilever is excited using a piezo element. This piezo is oscillated with a fixed amplitude at an operating frequency close to the free resonance frequency of the cantilever. The repulsive force acting on the tip will increase the resonance frequency of the cantilever. This will cause the vibration amplitude of the cantilever to decrease. The vibration of the cantilever is also detected using the cantilever deflection detection system.

The measured laser beam deflection or cantilever vibration amplitude can now be used as an input for a feedback loop that keeps the tip–sample interaction constant by changing the tip height. The output of this feedback loop thus corresponds to the local sample height.

An image of the surface is made by scanning over the sample surface in the X and Y direction. The sample structure image is now obtained by recording the output of the height control loop as a function of the tip position. The direction of the X- and Y-axes of the scanner is shown in *Figure 18-3: Scanner coordinate system*. The scanner axes may not be the same as the measurement axes, when the measurement is rotated, or the measurement plane is tilted. Therefore, the image X- and Y-axes are denoted by an asterisk to avoid confusion (i.e. X*, Y*).

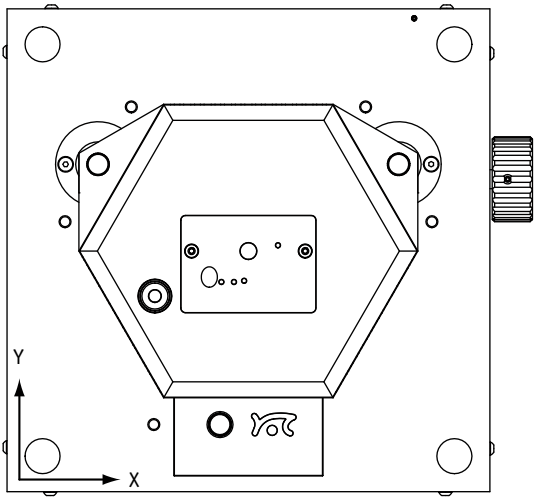


Figure 18-3: Scanner coordinate system

CHAPTER 19:

Technical data

19.1: Introduction

The specifications given in this chapter represent typical values of the Nanosurf FlexAFM system. The exact specifications of all components belonging to your system are given on the calibration certificate delivered with the instrument.

19.2: The FlexAFM Scan Head

19.2.1: Specifications and features

Scan Head Specifications	FlexAFM 100 µm	FlexAFM 10 µm
Sample size	Unlimited without sample stage; 100 mm on sample stage	
Maximum Petri dish height (fluid level in dish)	9 mm (6 mm)	
Manual approach range	30 mm	
Automatic approach range	1.1 mm	
Maximum scan range	100 µm (1)	10 µm (1)
Maximum Z-range	10 µm (2)	3 µm (1)
Drive Z-resolution	0.152 nm (3)	0.046 nm (3)
Drive XY-resolution	1.525 nm (3)	0.152 nm (3)
XY-linearity mean error	typ. 0.1%	
XY-flatness at maximum scan range	typ. 5 nm	typ. 1 nm
Z-measurement noise level (RMS, Static Mode in air)	typ. 0.3 nm	typ. 0.15 nm
Z-measurement noise level (RMS, Dynamic Mode in air)	typ. 0.16 nm	typ. 0.06 nm
Scan head dimensions	143 × 158 × 53 mm	
Scan head weight	1.25 kg	

(1) Manufacturing tolerances are ± 5%
(2) Manufacturing tolerances are ± 10%
(3) Calculated by dividing the maximum range by 16 bits

FlexAFM Scan Head Features	
General design	Tripod stand-alone, flexure-based electromagnetically actuated XY-scanner, piezo-based Z-scanner
Cantilever alignment	Automatic alignment for cantilevers with alignment grooves. Manual laser adjustment possible for special cantilevers.
Laser adjustment	No laser adjustment required upon immersion of cantilever into liquid because of SureAlign™ laser optics
Electrical connection to tip	Available
Sample observation	Top and side view in air and liquid
Visual magnification	Top: 13× / Side: 10×
Sample illumination	White axial illumination for top and side view. Transmission illumination with illuminated sample holder.
Cantilever holder	Cleanable and with replaceable cantilever spring
Operating modes (1)	Static Force Dynamic Force Phase Contrast MFM / EFM Spreading Resistance Force Modulation Lateral Force Kelvin Probe Force Scanning Thermal Multiple Spectroscopy modes Lithography and Manipulation modes

(1) See *Table 8-1: Operating modes and required modules* (page 90) for required modules

Compatible cantilevers

Cantilevers used in conjunction with the FlexAFM should have the following properties:

- Grooves that are compatible with the alignment chip used by Applied Nanostructures, BudgetSensors, NanoSensors, NanoWorld, and VISTAprobes.
- A nominal length of 225 µm or more, and a width of 40 µm or more.
- A coating on the backside of the cantilever that reflects (infra)red light.

19.2.2: Dimensions

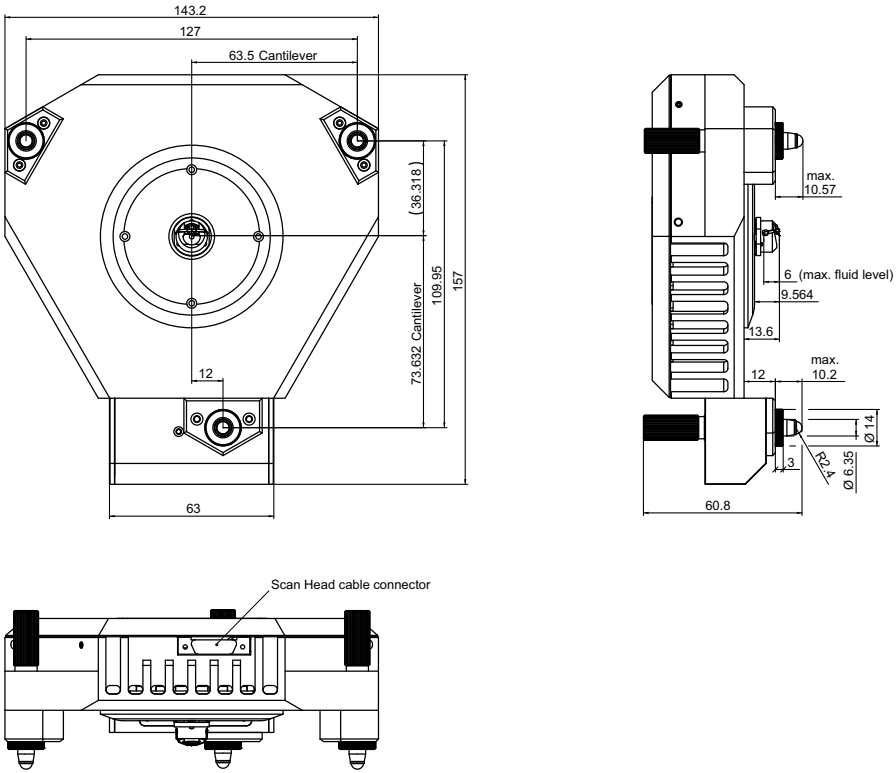


Figure 19-1: The Nanosurf FlexAFM Scan Head. All dimensions in mm.

19.3: The Easyscan 2 Controller

19.3.1: Hardware features and specifications

The Easyscan 2 Controller electronics	
Controller size / weight:	470×120×80 mm / 2.4 kg
Power supply:	90–240 V AC, 50/60 Hz, 100 W
Computer interface:	USB 2.0 (Appr. controller serial number 23-06-030 and higher)
Integrated USB hub:	2 Ports (100 mA max)
Scan generator:	16 bit D/A converter for all axes
Scan drive signals:	±10 V, no high voltage
Scan speed:	Up to 60 ms/line at 128 data points/line
Measurement channels:	16 bit A/D converters, up to five signals depending on mode.
Scan area and data points:	Individual width/height, up to 2048×2048
Scan image rotation:	0–360°
Sample tilt compensation:	Hardware X/Y-slope compensation
Spectroscopy modes:	Single point measurement or multiple measurements along a vector
Spectroscopy data points:	Up to 65535
Spectroscopy averaging:	Up to 1024 times

Table 19-1: General features and specifications of the Easyscan 2 controller electronics.

19.3.2: Software features and computer requirements

Nanosurf SPM Control Software

Simultaneous display of data in charts types:	Line graph, Color map, 3D view, …
User profiles:	Customizable display and parameter settings
Online processing functions:	Mean fit, Polynomial fit, Derived data, …
Quick evaluation functions:	distance, angle, cross section, roughness, …
Data export:	TIFF, PNG, BMP, ASCII, CSV, …

Nanosurf Scripting Interface

Applications:	Automating measurement tasks, custom evaluation functions, using third party measurement equipment, …
Included control software:	Windows Scripting Host: Visual Basic Script, Java Script, …
Remote control by:	COM compatible languages: LabView, MathLab, Visual Basic, Delphi, C++, …

The Scripting Interface has to be purchased separately for Easyscan 2 systems.

Lithography can also be performed via the scripting interface, but is more easily performed via the Lithography Window of the control software, or (when more advanced options are required) by purchasing the Lithography Option.

Computer requirements

For a detailed description of computer hardware requirements and supported operating systems, see *Nanosurf technical note "TN00477 — Computer requirements for Nanosurf Products"*. The technical note can be downloaded from the Support section of the Nanosurf website by all registered users.

19.4: Hardware modules and options

19.4.1: AFM modules

AFM Basic Module (1)	
Imaging modes:	Static Force (Contact): Constant Force (Topography), Constant Height (Deflection)
Spectroscopy modes:	Force–Distance, Force-Tip voltage
Tip voltage:	±10 V in 5 mV steps
(1) The AFM Basic Module is required for using AFM Scan Heads.	

Table 19-2: Features and specifications of the AFM Basic Module

AFM Dynamic Module (1)	
Imaging modes:	Static Force (Contact): Constant Force (Topography), Constant Height (Deflection)
Spectroscopy modes:	Force–Distance, Force-Tip voltage
Tip voltage:	±10 V in 5 mV steps
Additional imaging modes:	Dynamic Force (Intermittent Contact, etc.): Constant Amplitude (Topography), Constant Height (Amplitude)
Additional spectroscopy modes:	Amplitude–Distance
Dynamic frequency range:	15–500 kHz
Dynamic frequency resolution:	< 0.1 Hz
(1) The AFM Basic Module is required for using the AFM Dynamic Module.	

Table 19-3: Features and specifications of the AFM Dynamic Module

AFM Mode Extension Module (1)	
Additional imaging modes:	Phase Contrast, Force Modulation, Spreading Resistance, Lateral Force
Additional spectroscopy modes:	Phase–Distance, Current-Voltage, Current–Distance etc.
Phase contrast range:	± 90°
Phase contrast resolution:	< 0.05°
Phase reference range:	0–360°
Tip current measurement:	± 100 µA (3 nA resolution)

Table 19-4: Features and specifications of the AFM Dynamic Module

AFM Mode Extension Module (1)
(1) The AFM Basic Module is required for using the AFM Mode Extension Module.

Table 19-4: Features and specifications of the AFM Dynamic Module

19.4.2: Signal Module A

Signal Module A can be used to monitor microscope signals and add functionality (custom operating modes) to the Easyscan 2 system. It consists of electronic modules that are built into the Easyscan 2 controller as well as of a Connector Box that is externally attached to the controller. For information on installing Signal Module A, refer to *Section 2.2: Installing the hardware* (page 25).

The signals are available on twenty-one BNC connectors that are labelled with their signal names. The signal names and their function are listed in *Table 19-5: Monitor signals* and *Table 19-6: Custom operating mode signals*.

Signal name	Function
X-Axis	X-Position command of the Scanner. Is affected by Image X-Pos and the Imaging Area Rotation.
Y-Axis	Y-Position command of the Scanner. Is affected by Image X-Pos and the Imaging Area Rotation.
Z-Axis	Z-Position command of the Scanner. Is affected by the Z-Controller output, Ref. Z-Plane, X- and Y-Slope.
Tip Voltage	The voltage applied to the tip.
Approach	The voltage that determines the speed of the approach motor.
Excitation	The oscillating voltage that is applied to the piezo that excites the cantilever vibration.
Deflection	The raw cantilever deflection signal. Contains both the static cantilever deflection and the cantilever vibration.
Amplitude	The measured cantilever vibration amplitude.
Phase	The measured cantilever vibration phase. The phase is affected by the Reference Phase Mode Property setting of the Phase Contrast Mode.

Table 19-5: Monitor signals

The calibration of the monitor signals can be found by looking up the signal calibration in the Scan Head Calibration Dialog, reached via the menu “Options” >> “Config Scan Head...”. The magnitude of the physical signal can be calculated from the Monitor Signal voltage using the formula:

$$PhysicalSignal[Unit] = \frac{MonitorSignalVoltage}{10[V]} \cdot Maximum + Offset$$

The sum of the modulation inputs and the output value (for example of X-Axis) should not exceed the –10V to +10V range. The Excitation signal should not exceed the –5V to +5V range.

In addition, –15V and +15V voltage sources are available for driving small home-made electronics. The pin-out of this connector is shown in *Figure 19-2: Voltage source connector*.

Signal name	Function
Sync	An output that can be used to synchronize external equipment with the Easyscan 2 controller. This feature can be controlled with the scripting interface. For more information, refer to the Script Programmers Manual, topic "Object Reference" >> "Class Scan" >> "SyncOutMode" and "Object Reference" >> "Class Spec" >> "SyncOutMode"
User 1 Output	An analog output that can be used to drive external instruments using the controller. The User output can be used for special spectroscopy measurements.
User 2 Output	An analog output that can be used to drive external instruments using the controller. The User output can be used for special spectroscopy measurements.
X-Axis Input	The Input voltage is added to the X-Position command of the scanner.
Y-Axis Input	The Input voltage is added to the Y-Position command of the scanner.
Z-Axis Input	The Input voltage is added to the Z-Position command of the scanner. If the Z-Controller is turned on, it will try to compensate this voltage, as a result of which the Input voltage will be added to the topography measurement.
Tip Voltage	The input voltage is either added to the Tip-voltage set in the control software, or this Input connector has a direct electrical connection to the tip. The second option will be described in more detail in a future manual version (refer to the Nanosurf website).
Excitation Input	The input voltage is either added to the normal Excitation voltage, or only the Excitation Input signal is passed on to the Cantilever Excitation piezo. The second option will be described in more detail in a future manual version (refer to the Nanosurf website).

Table 19-6: Custom operating mode signals.

Signal name	Function
User 1 Input	An analog input that can be used to record the signal from external instruments in Imaging and Spectroscopy measurements.
User 2 Input	An analog input that can be used to record the signal from external instruments in Imaging and Spectroscopy measurements.
Aux 1	A connector that can be used for accessing signals that are not otherwise available. Contact your local distributor if you need to use this connector.
Aux 2	A connector that can be used for accessing signals that are not otherwise available. Contact your local distributor if you need to use this connector.

Table 19-6: Custom operating mode signals.

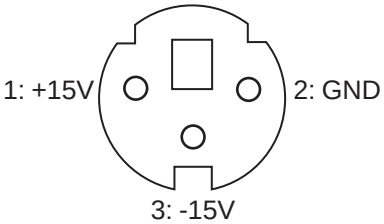


Figure 19-2: Voltage source connector. Connector as seen from outside.

Using the User Inputs and Outputs

The User Inputs and Outputs can be accessed through the Operating mode panel. Each signal can be calibrated with the User Signal Editor, which is accessed by clicking the corresponding "Config" button. This Section is only available in the Advanced user interface level. Refer to *Section 14.9: User Signal Editor dialog* (page 263) for a more detailed explanation.

Various other User Input and Output settings can be configured in the Signal Access page of the SPM Parameters dialog. Refer to *Section 14.8.1: Signal Access page* (page 259) for details on how to change them.

19.4.3: The FlexAFM Video Camera

Camera system:	Color top view / monochrome side view
Camera resolution:	3.1 MP for top view / 1.3 MP for side view
Zoom range:	4-fold digital zoom in 3 steps (1/2/4×)
Field of view:	Top: 2.0 × 1.5 mm / Side: 2.4 × 2.4 mm
Optical resolution:	Top: 2 µm
Focus:	Motorized, user-controlled focus for each camera
Video display:	Simultaneous display of top and side view
Video output:	Direct USB 2.0 connection

19.4.4: The FlexAFM Micrometer Translation Stage

Micrometer Translation Stage Specifications (stage only)	
Travel (XY)	13 mm in each direction (6.5 mm from center to all sides)
Repositioning precision	Better than 10 µm
Straight line accuracy	Better than 10 µm
Weight	0.75 kg